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EUROPEAN SCIENTIFIC NOTES **OFFICE OF NAVAL RESEARCH** **LONDON**

edited by Philip Fire and Don J. Peters

31 May 1981

Volume 35, No. 5

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COMPUTER SCIENCE

COMPUTER GRAPHICS AT THE UNIVERSITY OF GENEVA

The University of Geneva has some 9,000 students, which is large for Switzerland. The computer center at the university has its own UNIVAC 1100/60 which is also a large computer for a Swiss university, although most of the universities have access to a large computer somewhere. Actually, one of the world's largest computing facilities is located in Geneva at CERN, the European Center for Nuclear Research, and people at the university can use those computers although they must travel a few miles to do so. The Computer Science Department reports for purposes of teaching and research directly to the dean of the Faculty of Sciences, but it has an unusual administrative setup by which some of the staff of the department report to the Faculty of Science, some to the Faculty of Economics and Social Sciences, and some to the Faculty of Medicine. The director of the department, Bernard Levrat, reports directly to the director of the university. There are about 150 undergraduate students in the department; about 50 degrees (diplomas and licentiates) are awarded per year together with approximately one doctoral degree.

Levrat himself is a fascinating man who took his doctorate at the University of Michigan in 1963 in nuclear physics and then came back to Geneva to work at CERN in high-energy physics. There was at that time tremendous need for computation and very little competence in this area. Levrat happened to have become knowledgeable about computers while working on his doctorate, and found himself more and more pressed into supporting research through his computer expertise. In 1968 he was called to accept the first chair of computer science at the University of Geneva.

Christian Pellegrini received his PhD at this university in 1976 and Bertrand Ibrahim is currently a doctoral candidate; they are working on a fascinating project on computer graphics. Text processing by computer has become very commonplace, and many aspects of it are now performed routinely by clerical personnel, including secretaries, as distinguished from computer scientists. There is a wide variety of text-processing schemes, some more sophisticated than others; in general one can create text, examine it, modify it, add or delete particular segments. In many systems a particular section such as a paragraph can be taken out and moved; or a letter, for example, can be composed by taking a standard first paragraph, adding a made-to-order second paragraph, and then picking one of five standard third paragraphs, etc.



Figure 1: Screen Showing Finger Input Device Displayed

The aim of the project on which Pelegrini and Ibrahim are working is to allow similar processing of graphic material. This constitutes simultaneous implementation of three different things: man-machine interaction, computer graphics, and editing. The implementation is not terribly sophisticated, but the results are dramatic.

The basic equipment (Fig.1) consists of a plasma panel, a screen about 20 cm square (8" x 8") attached to a local microcomputer and also attached remotely to the UNIVAC main frame computer. Beneath the screen, a 512 x 512 matrix of crossed electrodes, controlled by the microprocessor, can initiate local breakdown in the enclosed plasma. Light is emitted at any of these 262,144 intersections which are addressed by the controller. The breakdown is self-sustaining until extinguished by a control signal. To the left of the screen are 80 infrared-emitting photodiodes, and to the right 80 infrared-sensitive phototransistors, each of which is capable of detecting whether the light from its corresponding transmitter has been interrupted. Because the computer can interpolate between two adjacent receptors, there are actually 160 resolution elements. A corresponding system of emitters at the top and receptors at the bottom of the screen creates similar resolution in the perpendicular direction for entering graphic information.

The basic picture is drawn by running one's finger or any other suitable object along the screen. A corresponding curve then appears in the form of lights. This image can be further processed or it can be stored in the computer memory or even on a "hard copy"—that is, a copy of the drawing on paper can be made. An example of a cartoonist's portrait of Mr. Ibrahim as it is presently stored in the computer is shown in Fig. 2. Had the screen been photographed, it would have looked very much like this except that some of the control instructions would also have shown. However, this figure is a copy of a drawing actually printed out by the computer remotely.

In addition, the system can be set up to have the screen appear to be pressure sensitive, i.e., messages can be sent to the computer by pressing on appropriate parts of the screen. For example, in one mode the lower portion of the screen is lit up in such a way as to resemble a conventional typewriter keyboard (Fig. 1), and one may then press on the key marked E to have the letter "E" appear where desired on the screen. Other typewriter keyboards can be made to appear, including lower case, mathe-

matical symbols, and the Greek and Arabic alphabets. Various mode-selection areas can also be made to appear on the screen. For example, the entire top of the screen can be covered with various possible directions. One of these was marked "annul." I experimentally pressed my finger on this point after I had drawn a picture, but nothing happened. I was then informed that the annul command had to be confirmed, lest a lot of work be carelessly wiped out.



Figure 2: Example of drawing made on the computer and subsequently stored and printed.

The basic drawing can be a simple geometric figure, something like Fig. 2, or something much more complicated. After it has been made, it can be processed in a wide variety of ways. For example by pressing the zoom "button," one can make the picture grow larger or smaller. One can also rotate the picture, or translate it (that is, move it left or right or up or down). One can also create a "rubber band" mode which causes different segments of the figure to be connected. Then again, one can also duplicate a figure or a piece of a figure. Thus one could draw some design, duplicate it, move the duplicate around adjacent to the original, then take another duplicate and move that around, until finally one had several duplicates to form a more complex geometric figure. One can also generate text with the typewriter mentioned above, zoom the text to the desired size and insert it in the picture in the desired place. In other words, one can in general edit graphics just as one commonly edits text in a text processor.

The sampling rate of the photoreceptors mentioned above is 50 per second; therefore one can draw a picture rather rapidly by moving one's finger across the screen and have the machine respond. However, to store the picture by brute-force methods, 262,144 binary memory elements would be required. While it is possible to attain this amount of storage in the microprocessor, it is expensive and not necessarily desirable, and in fact is not normally required. The storage is essentially in the screen itself; as discussed above, the plasma breakdown is self-sustaining at each "point" in the matrix. If it is necessary to store a curve while another one is generated, it must be stored in the UNIVAC, which is remote, and a few seconds may be required for access. Even then, however, the mechanism of storage is efficient: the initial point of the curve is stored, and since there are 512×512 resolution elements, this requires only 18 bits. Thereafter the machine records the direction in which the curve moves and the distance before the direction is again changed; again, comparatively few bits are required unless the curve is extremely complex.

Another modification is that used in recording photographs, for which a gray scale is required. The light emitted at a point can only be turned on and off, and therefore cannot represent variable intensity at that point. However, by dividing the 512×512 matrix of points into 102×102 groups of 5×5 points (or 170×170 groups of 3×3), one can turn on any number of lights within a particular group, thus getting 26 intensity levels in the one case or 10 in the other. I was shown quite good and recognizable photographs which had been stored and were displayed on the same screen by being called up out of storage.

Some rather clever data processing techniques are used with all of the above. For example, translating the picture across the screen involves changing only the location of the initial point; everything else remains the same. A zoom or a rotation amounts to multiplying every visible displacement by a transformation matrix. One may wish to enlarge a picture, add some detail into the drawing, and then reduce it back to its original size. These operations clearly lead to the possibility of round-off errors. The best way to avoid such errors is with a floating-point representation which permits a minimum loss of information after numerous manipulations, but which slows down the computation.

Comparable work is going on at one other place in the world to my knowledge, namely at the IBM research center in Madrid (ESN 34-9:464 [1980]). It seems clear that in the not-too-distant future, graphics processing as well as text processing will be quite generally available. (Robert E. Machol)

ENERGY

FUTURE ENERGY CONCEPTS

The Third International Conference on Future Energy Concepts was held from 27 to 30 January 1981 at the Institution of Electrical Engineers (IEE) Building in London. Of the 355 participants, approximately three-fourths were from the UK, and 23 countries were represented in the remaining one-fourth. Belgium, the United States, the Netherlands, the Republic of Ireland, Denmark, and Italy all had significant representation. (The Second International Conference held in 1979 at the same location was reported in ESN 33-5:180 [1979] and ESN 33:-10:405 [1979].) In conjunction with the present conference, exhibits were displayed in the Maxwell Room of the IEE. Principally from the Department of Energy (UK), these exhibits showed highlights of programs in wave energy, enhanced oil recovery, wind energy, conservation, geothermal energy, and energy from biological sources. Several private firms also exhibited designs for extracting energy from water waves. A soft-cover compilation of all the contributed papers entitled "Future Energy Concepts," (conference publication #192) comprises the conference proceedings. It can be obtained from the IEE conference secretary (P.O. Box 26, Hitchin, Herts. SG51SA, UK).

The conference consisted only of single sessions. The first session was introductory; the last consisted of a panel; in between, there were 79 contributed papers distributed by subject through 10 sessions.

The format of the sessions was somewhat different from much US practice in that each session had a chairman and a rapporteur or keynote speaker whose speech took most of the sessions time. The rapporteur summarized each session, pointed out the important or significant papers (often ignoring others), and usually posed discussion questions. In all the sessions, emphasis was not on scientific advances, but on the economic feasibility of a completed engineering project. Conservation

methods and policies were mentioned on several occasions but almost in passing, since this was an engineering meeting most of whose participants were from electricity boards, fuel boards, and others who were interested in supplying large-scale power.

Since the conference was heavily dominated by representatives of the electrical power generating industry, it was natural that one of the central problems of the industry (matching supply and demand) should be extensively discussed. By government order in the UK, natural gas is not used for generating electricity. Instead, electricity is supplied principally by coal-fired or nuclear generating plants which operate most efficiently at a fixed demand. The daily and yearly demand cycles are met by connecting more or fewer generating plants into the power grid. Unconventional sources of energy such as wind, tide, and solar are all basically intermittent and waves have characteristic frequencies different from that used in a power grid. Both of these attributes present problems when an unconventional source is connected to the power grid.

The chairman, Mr. R.C. Hills (assistant director of engineering of the Independent Broadcasting Authority of the UK), who formally opened the conference, set the tone of the meeting by stating that "what happens when the oil runs out is a question of importance to all civilized nations." Hills further noted that the North Sea oil might last as much as 20 or 30 years and that coal reserves would possibly last 200 to 300 years. After these somewhat disturbing facts had been presented, the opening address was made by Dr. A.A.L. Challis (chief scientist of the Department of Energy, UK) who gave a general view of energy consumption in the UK in the year 1978. Challis noted that the major uses of energy were for heat (60%) and transportation (24%). He added that since such a large percentage of energy supplies was used for heating, big conservation efforts should and could be made in the region of less than 100°C. According to Challis, domestic heating is accomplished by gas and coal about equally at the present time, while non-domestic heating is dominated by oil usage. In contrast, industrial process heating is coal dominated.

After stating that conservation needs a higher intellectual commitment and that there has been more commitment to demand than to conservation, Challis spoke specifically about electrical generation and noted that the DOE expenditures for unconventional sources of energy came

to a total of £9 million (\$20 million) in 1980. Coinciding with Challis' speech, the UK Department of Energy announced that a 20-meter horizontal-axis wind turbine generator was to be installed in the Orkneys. This 2 MW constant-speed machine will have rotatable tips with adjustable pitch to control the speed and, according to Challis, "the largest disc brake he has ever seen" to stop the machine if the wind is too strong. The generator is to be installed at a site where the average wind velocity is very high (20 MPH); mainland sites in the UK have approximately 1/2 of this. Challis closed by pointing out that there was a need for diversity of ideas and sources. He added that tidal power was in the realm of competition with coal and nuclear power as evidenced by the Severn Bore Project.

The energy outlook was discussed by P. Blakely (oil operations director, Imperial Chemical Industries Ltd.) who pointed out that the slope of the generally linear upward trend of energy use in the UK between 1970 and 1980 had begun to diminish as a result of lessened economic activity. In 1980 energy was in tight supply, a situation different from the fifties and sixties when expanding the usage of energy was easy. During the 1973-1979 period the development of alternative sources was very slow. Blakely concluded by saying that "the free, developed world had a choice between limited growth and vigorous development of alternative energy sources." He also said that this development was expensive and the preferred technologies should be identified quickly. According to Blakely there was a need to identify the development time and capital costs, and since governments had played an increasing role in searching for solutions to the energy problem, he hoped that they had the right direction.

Prospects for geothermal energy were discussed by rapporteur Dr. J.D. Garnish (Energy Technology Support Unit, UK), who said that this unconventional energy source was probably the least familiar to a UK audience, even though it was the one in which there was the most commercial experience overseas. He noted that one of the papers ("Prospects for the Further Exploitation of Geothermal Energy" by J.R. Shaw and P.E. Robinson [of Merz and McLellan Consulting Engineers, London]) provided a useful summary of overseas experience of the generation of electricity from high enthalpy sources ($T \sim 300^\circ\text{C}$) of natural water or steam.

The generation units are relatively small (50-100 MW); the present worldwide capacity of all of them taken together is approximately 2,000 MW with projections to the year 2000 of between 7,000 and 15,000 MW. Many of these sources are located near the tectonic plate boundaries. Although small, these local sources can make a valuable contribution especially in the underdeveloped countries. Experience shows that geothermal power plants have high reliability and that, although the exploratory drilling risks can be large, the electricity generated is often cheaper than that obtained from fossil fuels.

More unusual (and therefore less developed) geothermal sources are "hot dry rock" and low enthalpy, which are found in regions other than plate boundaries and therefore have great potential through availability. Low enthalpy water ($T \sim 70^\circ\text{C}$) can be found in many parts of the world. The hot dry rock scheme consists of using a large underground bed of this material as a heat exchanger to heat the fluid (water) which is pumped in and out of the bed. These installations have been used in granite which is expensive to drill to the required depths (8,500 ft.) and require a large fractured rock bed. It is hoped to extend the use of hot dry rock to beds other than granite, but although drilling in sedimentary rock is faster, it is afflicted with more problems. By the year 2000, perhaps 1% of the power supplied may come from these sources. Garnish pointed out that since these sources have relatively low temperatures, they are inherently inefficient to use and consequently large quantities of heat are not utilized. (The efficiency η is related to Q_h , the heat absorbed from the hot reservoir at temperature T_h , and Q_c , the heat transmitted to the cold reservoir at temperature T_c , by $\eta = 1 - Q_c/Q_h$ and, for a Carnot engine, $Q_c/Q_h = T_c/T_h$). No methods have been developed yet for disposing of these large quantities of heat, and the environmental effects have not been considered.

The keynote speaker for the session on wave and tidal power, Dr. C.O.J. Grove-Palmer, is manager of the UK Wave Energy Program. This session was unique in that the rapporteur spoke briefly and then each paper was presented by one of the authors. Grove-Palmer said that these energy sources required an entirely new technology. Unlike solar, wind or geothermal power, all of which have been in use for at least 20 years, progress in wave and tidal power is hindered by the lack of an established academic background in the engineering departments

of the universities. Waves are a diffuse source of energy and therefore require large structures to realize significant energy capture. This in turn means large capital investment in machines which must operate in a hostile environment. Off the Hebrides the power in waves is 45-50 kW/m of which current technology may send 7-8 kW/m out of the machinery into the power grid. In 1978 the estimated cost of wave energy was 20p/kWh (45¢/kWh); since then the estimates have decreased somewhat while costs of other energy sources have increased.

The devices presented for wave power were those that couple a working fluid (air) to the waves and extract energy by allowing the working fluid to drive a generator through a turbine. Often baffles or valves are required to make the flow unidirectional although one type of turbine will operate at reduced efficiency with a flow in either direction. Some discussion was also given to problems of matching the devices to the waves by proper choice of the resonant frequency and energy absorption bandwidth.

Transmitting large amounts of energy to the shore is a non-trivial task; the common assumption is that the wave energy will be converted to electrical energy before being transmitted, and several papers dealt with various schemes to accomplish this. Both AC and DC were suggested and both have advantages. It was pointed out by one questioner that some schemes required electrical components which were beyond the present state of the art in several technologies, (e.g., an unavailable 132 kV AC insulated flexible underwater cable). It was also noted that many wave energy schemes required flexure of some part of the device at a rate of approximately once every 10 seconds (period of a normal wave) and should remain in service for at least 5 years; which meant lasting through at least 10^7 cycles. As another participant noted, these criteria meant that wave power devices are very good fatigue testing machines.

Dr. J.P. Musgrove (Univ. of Reading, UK), rapporteur for the Wind Energy Systems session, said that the EEC has a very small program in wind energy compared to the Americans who are leaders in this area. In the UK over one-third of the present total power usage is available in offshore wind turbine sites (100 TWh out of a total of 230 TWh). Offshore sites are preferred because land space is limited and because some people find the wind machines objectionable both visually and aurally.

The wind is not a steady source of energy. One of the papers ("Effects of

Geographical Separation of Clusters of Wind Generators," R.J. Lowe & G. Alexander [Open Univ., Milton Keynes, UK]) compared wind speed spectra for four different sites. The authors found that, for arrays spaced over 100 km apart and periods of time to 10 hours, there was very little correlation between the outputs of wind turbine arrays. From this they concluded that geographical diversity would be of great value in reducing fluctuation in the amount of energy supplied by the wind from large-scale installations.

Actual wind-driven generators discussed were relatively few: a study of variable pitch controls for the horizontal-axis 3-bladed 5-m-diameter machine at Swansea; development of the horizontal-axis 3-bladed 17-m-diameter machine at Aldoborough; and a vertical-axis 3-bladed 6-m-diameter test machine at Reading. Since the power output from a wind turbine increases as the square of its rotor diameter, power generating companies are interested in the large sizes which are more economic if the costs increase at a slower rate. Sizes mentioned were 60-100 m diameter machines, each with about 3 MW output, arranged in arrays of up to 200. Significant parameters affecting output of these systems are rotor diameter and mean wind speed. Significant parameters affecting the cost are rotor size and performance, size of the support structure, and operational life. It is claimed that for offshore wind turbines, the main uncertainty in generation costs is the uncertainty in the mean wind speed. Since a 60-m machine is estimated to cost £1.5 million (\$3.5 million) it seems likely that more studies, especially of offshore winds and lighter support structures, will be carried out before large-scale arrays of this type are actually constructed.

A possible future was discussed by Dr. G. Leach (International Institute for Environment and Development, London) in an evening lecture on "The Plausibility of Zero Energy Growth". Leach said that the "law" of energy use being correlated with income is now changing. He added that more efficient methods of utilizing energy have been adopted in most of the developed countries in Europe—especially France. Britain, however, has been an exception to this general trend. Since 1923, there has been very little change in the amount of electricity delivered: 25-27-MWh/capita in the UK.

Leach believes that energy consumption by individuals and industries depends on patterns which can be changed and he presented several graphs from which he concluded that changes in these use

patterns have already begun. He concluded by emphasizing that he was talking about projections made from trends and that he was not introducing any radical new ideas about conservation.

The final session consisted of a panel composed of Sir Herman Bondi (chairman, Natural Environment Research Council, London), Prof. D.T. Swift-Hook (Central Electricity Research Laboratories, Leatherhead, UK), Dr. M. Klein (Electric Power Research Institute, Menlo Park, CA) and W.C. Patterson (international editor, Bulletin of the Atomic Scientists, UK). Swift-Hook nicely summarized the prevailing consensus. In the future the UK is committed to coal and nuclear power but the price of wind power and other types of power is decreasing. However, by the year 2000 the contributions of wind energy, solar energy, wave energy and tidal energy will represent only a small part of the total. (John R. Neighbours)

THE TWELFTH INTERNATIONAL POWER SOURCES SYMPOSIUM

The International Power Sources Symposium (IPSS) is a biennial meeting held in Brighton, England; the 12th such meeting was held from 15 to 17 September 1980. This symposium had over 300 registrants. The majority of the participants were from the UK, with US and European scientists accounting for most of the others. There were two representatives from the People's Republic of China and six from Eastern European Communist countries. Topics covered at the symposium included lithium/thionyl chloride and lithium/sulfur dioxide batteries, sea water batteries, alkaline batteries, lead-acid systems, metal/air batteries and some individual papers on general aspects of batteries/fuel cells such as electrodes, thermal management, and electrolyte improvements.

The author's specific areas of interest at this symposium were those of lithium batteries and the more fundamental and general aspects of battery-related processes and materials, e.g., thermal management, intercalation compounds and solid ionic conductors. Because manuscripts of the papers presented at the symposium will be available (in mid-1981) in a generally-available publication (*Power Sources - VIII*, edited by Dr. James Thompson, published by Academic Press), only selected ones are discussed here with emphasis on those in the areas mentioned above. Answers to questions posed at the symposium and comments are included in the following summaries.

In response to a suggestion made at a previous IPSS meeting and as an

experiment, an informal discussion on the topic, "Have Lithium Batteries a Commercial Future?" was held near the middle of the symposium. The discussion was vigorous; the question posed by the title was not definitively answered. While an attempt was made to guide the discussion according to the topical outline of manufacturing aspects, corrosion, supplies, and safety, the last-named topic dominated the proceedings. In this regard, some of the comments were marked by generalizations and illustrated a common tendency to lump lithium batteries into one category with regard to safety. The general impression conveyed by this part of the discussion was that safety, specifically in lithium sulfur dioxide and lithium thionyl chloride systems, was still the major concern.

Lithium batteries are becoming more easily available on the commercial market. The Japanese, for example, are producing about 20-million lithium/manganese dioxide button-type batteries annually for use in calculators, etc., and they expect to increase production.

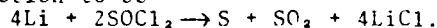
A representative of the Foote Mineral Company, Exton, PA, predicted that there would be ample supplies of lithium available, at least for the rest of the present century. (It was not entirely clear whether this projection included provision for possible large-scale use of this element for the manufacture of such products as load-leveling and vehicular-propulsion batteries.) At the present time, suppliers throughout the world are planning to increase the available stores of lithium by some 30 percent. The price of lithium will not be determined by its use in batteries. In point of fact, this element will continue to be employed primarily for aluminum production, the manufacture of various types of greases, and the production of catalysts.

Little mention was made of rechargeable battery systems which operate at room temperature. Two of the leading organizations which are working or have worked in this field, EIC Laboratories and Exxon, were not represented in the program. The impression gained by the author was that most participants believe that rechargeable types are in a very early stage of development, and therefore they do not consider them in the same context as the advanced battery systems.

In the first paper presented at the symposium (coauthored by J.P. Gabano and G. Gelin, Société des Accumulateurs Fixes et de Traction [SAFT] LeClanché), Gabano discussed the recent work on eliminating the voltage delay in lithium-thionyl chloride batteries resulting from storage,

particularly at elevated temperatures. The approach used by SAFT has been to neutralize the aluminum trichloride with added lithium oxide (Li_2O). The mechanism proposed by Gebano and Gelin involves the reaction of the Li_2O with aluminum trichloride and thionyl chloride to form a complex or adduct (suggested to be $\text{AlCl}_3 \cdot \text{SO}_2$) which subsequently reacts with the surface film of lithium chloride to reduce the extent of film coverage. Hermetically sealed cells have been constructed and tested. These cells were not supplied with a vent and for this reason it is believed that they would explode at temperatures above the lithium melting point (200°C). The presence of the complex does not change the cell conductivity. The cell performance remains essentially unchanged, except for a reduction in delay time for voltage recovery, provided the electrolyte concentration is the same.

The unequivocal determination of the chemistry and products produced during the discharge of lithium-thionyl chloride batteries has been a goal of numerous investigations since the discovery of the battery system. The second paper at the symposium was presented by J.C. Bailey (coauthored by J.P. Kohut) of Union Carbide Corp.; it addressed the question of reaction products. Using the relatively simple techniques of gravimetric and elemental analyses, the authors were able to show that a number of possible discharge reactions could be eliminated. The equivalent weight of the solid formed during the discharge along with the amount of sulfur and chlorine in the products suggests the overall discharge reaction to be



This appears to be generally applicable to the temperature range -50 to 71°C at all depths and rates of discharge investigated in the study. At the higher temperatures (near 71°C) and at deep discharge conditions, further reduction may occur. Sulfur dioxide has been identified and the pressure produced (55 psi) agrees with that expected. The authors corrected the results to allow for contributions from corrosion. These contributions were essentially absent at room temperature; at higher temperatures or when the temperature was varied, the contributions increased. The authors were not able to infer much about the relative reaction rates of the possible mechanisms.

Participation in international symposia by representatives from the People's Republic of China is becoming increasingly common. Two representatives from the Tianjin Institute of Power Sources

were present at this meeting. Mr. Fu-ying Pan delivered a paper by D-Z. Bi, J-Q. Wang and Y-H. Sun on the use of α -titanium dioxide (TiO_2) as a cathode material for lithium secondary cells operated at room temperature. This paper was one of a series presented by scientists from this group. The related papers were presented at the 156th meeting of the Electrochemical Society in Los Angeles in October 1979 and the Workshop on Lithium Nonaqueous Battery Electrochemistry in Cleveland in June 1980. The work reported in this symposium involved the electrochemical behavior of α - TiO_2 in lithium perchlorate-propylene carbonate electrolyte solutions. The results showed TiO_2 to be electrochemically reversible in these solutions. Both the results and the cycling behavior indicated that α - TiO_2 was a possibly useful cathode material for low-voltage (1.5-1.8 V) and low-discharge-rate cells. It was noted that the TiO_2 underwent marked color changes, from white to dark blue-grey, during reduction.

In another paper presenting results possibly applicable to rechargeable lithium systems, E. Peled and H. Yamin (Tel Aviv Univ.) described the lithium/polysulfide combination in a tetrahydrofuran solvent. Lithium stability was reported to be achieved via the formation of a lithium sulfide "solid electrolyte interphase" (SEI) on the lithium surface. Passivation of the lithium increases as the polysulfide concentration builds up. Rechargeability in the system has been a problem; however, self-discharge current rates are low enough to be acceptable for secondary applications. The mechanism is interpreted to be short circuits formed by lithium metal deposition within and isolated by the SEI. This leads to a low cycling efficiency. One other problem that would require solution prior to battery development is the low conductivity of the system, due in large part to the SEI; migration of the lithium ion through the SEI is concluded to be the rate-determining step.

A.N. Dey of P.R. Mallory & Co., Inc. (now Duracell International, Inc.), described a super-high-rate lithium-thionyl chloride battery designed for laser designator applications. This system has one of the highest power densities known for batteries. The battery provides a 24 V pulse sequence of 20 A for 29 ms followed by 3.2 A for 22 ms, repeated for a total of 20 seconds; this sequence is repeated in turn every 3 minutes. The cells employ multiple tabs and long electrodes to minimize the effects of cathode current limitations. They are flat, cylindrical cells three inches in diameter

by nine-tenths of an inch high. To achieve the maximum discharge rate, cathode thicknesses less than or equal to ten mils are used. Thirty-five to forty pairs of electrodes are used per cell. The cells exhibit approximately 14 milliohms internal impedance, indicating a low level of polarization. Overall, they are 20 ampere-hour batteries exhibiting an energy density of 150 watt-hours per pound. During characterization, cells have been discharged at a nominal 100 A rate. In a test period lasting approximately 8 minutes, the current drawn through a fixed resistive load fell from an initial value of 100 A to a final value of 85 A. There was an accompanying rise in cell temperature. Venting occurred when the cell wall temperature reached 80°C. Under short-circuit conditions, a maximum current of 1500 A was observed; voltage was at about the 1-volt level for 0.12 seconds before venting. No explosions occurred. For sustained high-discharge-rate applications, some form of cooling would be necessary. While venting was observed at a cell wall temperature of 80°C, the internal temperature must have been considerably higher. Venting would not be expected at storage temperatures of 80°C. In the most recent formulations, cathode additives have been used. Dey would not comment on the nature of these additives.

In a paper entitled, "Corrosion of Glass-to-Metal Seals in Lithium-Sulfur Dioxide Cells," S.C. Levy, C.J. Leedecke, B.C. Bunker and C.C. Crafts of Sandia Laboratories presented the results of an investigation of the premature failure, during storage, of lithium-sulfur dioxide batteries. The premature failure was observed, beginning after about 18 months of storage, well before the expiration of the expected shelf-life of 5 years. The principal reasons for failure were self-discharge due to corrosion and venting at the glass-to-metal seal. (Most seals are expected to exhibit such failure when approximately 30% of the glass is etched away.) The corrosion process began at the metal and progressed toward the pin. A model based on the appearance of lithium in the corrosion products and underpotential deposition has been formulated to account for the corrosion. Lithium ions from solution were believed to adsorb sufficiently at the glass to facilitate underpotential deposition at the outer conductor. The lithium thus produced reacted with the glass and a further lithium deposition/reaction occurred at the corrosion boundary causing

it to progress toward the central pin. Several glass compositions were tested; the best resistance to corrosion occurred in the low silica glasses. The authors have now produced a glass at Sandia which exhibits a very slow corrosion rate. This is identified as Ta-23 glass.

Lithium-manganese dioxide batteries have been introduced on a moderate scale into the commercial market, primarily by the Japanese. Current production of these batteries in Japan is about 20 million per year (a figure mentioned earlier in this article), split about evenly between Sanyo and Matsushita. These batteries, which range in size from about 30 mAh to 1000 mAh, can be used effectively in calculators, electronic watches, clocks, and other such applications. Hironosuke Ikeda and co-workers from Sanyo Electric discussed the "Characteristics and Applications of Li-MnO₂ Cells." Ikeda's work, using x-ray diffraction spectroscopy and ion micro-analysis, has led to a model of the mechanism for the discharge based on intercalation of Li⁺ into the MnO₂ structure to form LiMn(III)O₂. No evidence for Mn₂O₃ or Li₂O in the products was observed. These had been previously proposed as possible reaction products in the process responsible for cell voltage levels. The lithium-manganese dioxide batteries have been produced in flat, multilayered, cylindrical and spiral structures. They generate approximately 3 volts and exhibit flat discharge curves. The capacity at -20°C is about 70% of the room-temperature capacity.

"Developments in Solid State Batteries" were discussed by Dr. J.R. Owen of Imperial College. Owen works with Dr. B.C.H. Steele whose research over the past few years has concentrated on solid, fast ionic conductors. The two scientists have been attempting to develop materials with possible battery applications and oxide ion conductors. The latter are potentially useful for sensor and electrode applications. Owen described investigations of solid-state cells composed of metal electrodes, solid electrolytes (e.g., LiI (Al₂O₃) or Li⁺-doped polyethylene oxide) and intercalation cathodes such as TiS₂, V₂O₅, and CoO₂. Diffusion coefficients for lithium ion in these cathode materials have been measured (10^{-7} cm² sec⁻¹ for V₂O₅; TiS₂ shows anisotropy with $D = 10^{-8}$ cm² sec⁻¹ along the crystal "channels" and 10^{-13} cm² sec⁻¹ across the crystal). Cells of the composition Li/PEO/V₂O₅ have been operated at about 100°C. The initial open-circuit voltage was 3.16 V. Systems of this type show promise as future all-solid-state battery systems.

One of the recognized problems limiting the range of applicability of batteries exhibiting high open-circuit potential and high energy density, particularly those based on lithium, is the limited solubility of electrolytes in the solvents necessary to build stable systems. Additives to increase this solubility have been investigated periodically during recent years. For alkali metal-based systems, the crown ethers have attracted attention because of their known complexing ability toward the various alkali metal ions. This application of crown ethers, and dicyclohexane 18-crown-6 (DC18C6) in particular, to potassium salts in selected solvents including toluene, methanol and 1,4 dioxane was described by N.R. Young and A.O. McDougall in their paper, "The Use of Crown Ethers in Electrochemical Cells." The addition of DC18C6 increased significantly the concentration of salts such as KCl in methanol where ion pairing was not a problem. The effect in toluene was less significant. Increases in conductivity were less than expected, but were present. Viscosity effects producing lower mobility at higher crown ether concentrations and the substitution of the DC18C6K⁺ species or K⁺ as a charge carrier were believed to be responsible for the lower than predicted conductivity. The crown ethers have drawbacks for practical applications. All are apparently toxic and some are suspected of having biological activity. In addition, they are relatively expensive. One of the more interesting potential applications, the development of polymeric systems containing crown ethers, was mentioned, but polymerized crown ethers had not yet been prepared by the authors.

"Long Life Divalent Silver Oxide - Zinc Primary Cells for Electronic Applications" was the subject of a paper presented by E-S. Megahed and D.C. Davig of the Ray-O-Vac Corporation. The paper contained practical solutions devised by the authors to alleviate problems of voltage stability, cell stability, and shelf stability of small silver (II) oxide-zinc cells. The voltage stability was controlled through a double reduction treatment of the AgO pellets. In this process, the AgO pellets were first treated with a methanol-potassium hydroxide solution, a mild reductant, to form a surface layer of silver (I) oxide (Ag₂O), followed by a hydrazine treatment to form a silver surface layer. The exact balance of the two reductants was not specified, but the resultant behavior of cells produced was sensitive to the thickness of the Ag₂O and Ag layers. Thin coatings produced cells whose voltages rose during

discharge to values above the desired value of approximately 1.6 V. Thicker coatings reduced the capacity and hence the advantage of Ag_2O over Ag_2O -containing cells. Cell instability was reduced through the addition of cadmium sulfide to reduce oxygen evolution and cell self discharge. Membrane selection influences silver diffusion and self discharge. The combination of these approaches has resulted in cells which can be stored at 60°C for up to 4 weeks with 10-20% loss in capacity. Storage at temperatures as high as 80 - 90°C can be accommodated, although no time limit was specified before decomposition occurs. Cell corrosion can occur at 90% relative humidity, but this was not observed to be a problem in these cells.

During the past few years, H.F. Gibbard and C.C. Chen of the Gould Laboratories have been investigating the thermodynamics, heat production, and thermal management of batteries. In their paper presented at the symposium, Gibbard discussed "Thermal Management of Batteries" and paid particular attention to the modeling and thermal management aspects of nickel-zinc, lead-acid (load leveling) and lithium-iron sulfide batteries. The method, developed by Gibbard and Chen, involves the calculation of heat generated by the battery taking into consideration the thermal dissipation which includes heat flow. In general, the temperature change within a battery is given by the adiabatic temperature change corrected for the thermal efficiency and the heat transfer of the system. Comparisons between calculated temperature changes and those measured have shown sufficient accuracy to lend confidence to the approach. For example, in work reported earlier, the center cell temperatures for 50 Ah and 225 Ah-capacity (C) nickel-zinc cells were predicted with an accuracy of about 2°C for discharge rates of C/5 to C/1 and charge rates of C/5 to C/8. The necessity for thermal management is particularly important in certain battery systems. The calculations for the cell configurations treated by Gibbard indicate that significant temperature increases can occur within the batteries unless some effort is made to provide cooling. For example, increases of over 30°C are possible in their Ni-Zn system. Such increases can cause the battery to enter a temperature regime where the lifetime is significantly shortened. Conversely, in the high temperature Li-FeS system, insulation and control of heat dissipation are also important.

Thermal batteries were the subject of a combined review and experimental

paper entitled, "A Review of Recent Developments in Thermal Batteries," presented by A. Attewell of the Royal Aircraft Establishment, UK, and A.J. Clark of Mine Safety Appliances Co. Ltd. (MSA). This paper was a revision of the paper originally scheduled for presentation. The authors presented a good review of calcium-calcium chromate thermal batteries: their advantages and shortcomings. Included in the latter are the problems associated with calcium-lithium alloy formation, precipitation of the double salt KCaCl_2 , the complex reduction mechanism of calcium chromate and the possibility, under certain conditions, of thermal runaway. In the new-results part of the presentation, the present state of development of thermal batteries containing lithium anodes and the recent experiments in the lower-temperature tetrachloroaluminate systems were discussed. The lithium-iron disulfide systems can give electrode efficiencies approaching 90% and operating durations of up to 1 hour. Several approaches to the lithium anode structure and composition are being investigated by workers in the field. The authors are looking at pure lithium systems (liquid at the operating temperatures). Other laboratories are investigating alloys such as lithium-boron (at the Naval Surface Weapons Center [NSWC]), lithium-silicon, and lithium-aluminum. The US Air Force Academy and the USAF Aero Propulsion Laboratory are among these exploring the chloroaluminate melt systems. In the paper, the authors contrasted the liquid lithium electrode system with the lithium-silicon battery of approximately equal size developed at Sandia. The MSA battery is reported to have a greater usable volume of active materials and to exhibit a higher energy and power density. Perhaps the most important conclusion at this stage is that new technology is available for the development of thermal batteries much larger than possible in the older systems and that such batteries will exhibit improved energy and power densities as well. (Jerry J. Smith, Office of Naval Research, Code 472)

ENGINEERING

MICROWAVE MEASUREMENTS IN LAUSANNE

There are two technical universities in Switzerland. I visited one of them, l'Ecole Polytechnique Fédérale de Lausanne (EPFL), which is in the French-speaking part of the country. The other is in German-speaking Zürich. Both technical universities are institutions of the Swiss federal government unlike the other universities which belong to the cantons (equivalent to states in the US).

In 1970 a new chair of electromagnetics and "hyperfrequencies" (300 MHz to 300 GHz) was created at EPFL under Prof. Fred Gardiol who had spent many years in the US. He was joined in 1978 by Prof. Mario Rossi, whose field is acoustics, and Gardiol's department became LEMA, Laboratoire d'Electromagnétisme et d'Acoustique. Unfortunately, Gardiol was ill during my visit to LEMA and I did not meet him till later, when he kindly gave me a copy of his newly published book, *Hyperfréquences*, in which he covers both theory and technology. The book is published by EPFL as Volume XIII of a 21-volume French language series, *Traité d'Electricité (Treatise on Electricity)* which is similar to but wider in scope than the post-WWII MIT Radiation Laboratory Series. In Gardiol's absence, I was hosted by Jean-Claude Besson who is one of his assistants and whom I had met before.

EPFL as a whole has some 2,000 students. In Gardiol's department there are 16 people, including 6 who work in acoustics. Apart from Gardiol and Rossi, all of these people are assistants and are mainly "federal" employees, although some assistants are sponsored by private foundations or by the Swiss National Science Foundation. Almost all the assistants devote some 30 to 50% of their time to teaching, and spend the remaining time working on their theses or on projects assigned by the professor. It is possible to obtain the doctorate 4 years after the first degree, but it usually takes longer. The cost of the research itself is mainly borne by the Swiss National Science Foundation, but sometimes industry comes with a specific problem it wants solved and then funds the necessary work.

Most of Switzerland's important buildings are constructed of sandstone. This was true 800 years ago and, to a great extent, is still true today. Lausanne's beautiful cathedral, built in the 12th and 13th centuries, is an outstanding example. Modern heating has been added to keep the buildings warm in winter.

This has created considerable temperature and humidity gradients across the masonry which vary with the time of day and the changing weather. As a result, the sandstone developed the rather nasty habit of "breathing," with moisture moving to and fro within the stone and at the same time actually transporting material. This has led to an accelerated rate of erosion, with material being brought to the outside and shed. The problem is a serious one, and Jean-Claude Besson has been developing a method using a microwave probe to measure the water content in sandstone for diagnostic purposes. The probe used was a coaxial cavity, abruptly terminated in an open circuit. The outer conductor was covered with lossy material on the outside to prevent currents from flowing on it. The fringing field at the open circuit penetrated the sandstone and the effects were measured by a determination of the resonant frequency and of the Q of the cavity. A good calibration curve is necessary but was difficult to obtain, since it was a function not only of humidity, but also of the grain-size of the particular stone. Nevertheless, reasonable success was claimed with this investigative tool at this early stage of the study. In connection with this work, another probe was studied to measure the moisture content of sand. This probe also was an abruptly open-ended coaxial cavity; it differed from the first in that the outer conductor continued beyond the coaxial structure to form a cylinder with a diameter well below cut-off. A plastic insert at the coaxial end of the cylinder sealed the coaxial cable and permitted the cylinder to be filled with the test material for reflection coefficient measurements. The wave in the cylinder was evanescent and the reflection coefficient was therefore affected only by the material near the coaxial open circuit. Calibration with liquids was found to be easy with low dielectric constant and low-loss material, but no such materials were found with high dielectric constants. Measurements with solids were found to be critically dependent on the exact nature of the contact at the coaxial interface.

Other workers at LEMA investigated small, loaded cavities for use in frequency standards. In one case, a cavity which was 15 cm in diameter and 15 cm long gave a Q of about 6,000 at 1.4 GHz. It was designed for a hydrogen maser and was loaded with an internal, thin, slotted, metallic cylinder. As a tuning control, its temperature was adjusted and very precisely controlled (to an

accuracy of 10^{-3} °C). Another cavity was loaded with alumina and had a Q of about 4,000.

A radiometric project, concerning the remote sensing of moisture in the soil and including hardware development, was undertaken together with the Department of Agriculture of EPFL. This is clearly a subject of considerable importance, not only in Switzerland, but worldwide, that could lead to the prediction of crop abundance or failure, or perhaps could form a trigger for remedial action. A joint paper on this subject was prepared in cooperation with Prof. Erwin Schanda from the University of Berne (see the following article, p. 191) and was presented at the 10th European Microwave Conference (ESN 34-11:512 [1980]). A correlation between microwave emissivity and soil moisture content had been established but it was found difficult to interpret the results due to the dependence of the measurements on both soil consistency and vegetation cover. A different approach to the same problem has been reported in these pages (ESN 34-9:433 [1980]) where, at the University of Delft, under Prof. L. Krul, echo analysis of an active X-band radar was used in attempts to determine crop and soil conditions. The hardware built at Lausanne operated at 2 bands, 2 to 2.4 and 3.6 to 4 GHz, both using a common 1-meter diameter dish-antenna. The radiometer was built in an impressively short time, being completed in less than 6 months. It uses a liquid hydrogen-cooled noise source as reference noise temperature, switched by a PIN-diode. The preamplifier has a 4 dB noise figure. The first experiments were conducted with the equipment held off the ground by a crane and some problems were encountered from local "microwave pollution." During my visit, the equipment was being readied for installation in an aircraft. When operational, the results will be interpreted by the Department of Agriculture.

Theoretical studies of mono-mode and multi-mode optical fibers with variable refractive indices were carried out in a separate study. Two approaches were used for calculating the response with arbitrary variations of the refractive index. The first approach used "staircase" approximations; the second used a power series expansion of the profile and assumed only small variations in refractive index. Asymmetric optical guides where variable refractive index material was deposited in a trough, were also studied theoretically.

The team at LEMA clearly showed their enthusiasm for the work they are involved in. Their work is relevant and most ably guided by Gardiol. (T.C. Cheston)

REMOTE SENSING AND PRECISION MEASUREMENTS IN BERNE

In a recent liaison visit to Berne, Switzerland, I was accompanied by Jean-Claude Besson, who had been my host during an earlier visit to l'Ecole Polytechnique Fédérale de Lausanne (see preceding article in this issue). Our first stop in Berne was at the University of Berne, where we visited Prof. Erwin Schanda. Schanda is the director of the Institut für Angewandte Physik (IAP, Institute for Applied Physics) and he also heads the Department of Microwave Physics. The research group in Schanda's department has 14 staff members who are primarily involved in remote sensing projects, many of them in cooperation with research efforts in the US and Germany.

Schanda has special interest in the emissivity and reflectivity of natural snow cover and their daily variations, at frequencies from 1.8 to 94 GHz. It appears possible to interpret satellite-obtained information and to differentiate between new snow that has never melted and old snow. Three forms of snow can be recognized easily: winter snow, which has never melted; spring snow, where melting alternates with refreezing; and summer snow, where the whole pack is wet. The penetration of snow by microwaves is very much a function of its dryness, ranging from 10 meters for dry, winter snow, to a few centimeters for wet snow. The important parameter to determine is the total volume of water stored in the snow, rather than the depth of the snow itself. Schanda stated that the emissivity of snow at short wavelengths could be correlated to the amount of water up to a depth of 20 to 30 cm. As yet, there is no satisfactory way to determine the quantity of water at greater depths. In the interpretation of the results, both reflectivity and emissivity over wide bandwidths are used. Much of the experience comes from an experimental station situated on the Weissfluhjoch, one of Switzerland's famous glaciers.

Vegetation and soil moisture are being studied by Schanda's group, again with both back-scatter (radar) and emissivity (radiometer) measurements in the 1 to 12 GHz range. The initial investigations have consisted of a systematic study with the equipment operated from a crane. The work is being supported by the Swiss National Science Foundation.

The group also studies the atmosphere and its composition by measuring and analyzing radiation from it at millimeter wavelengths. Measurements are taken both from the ground and from an aircraft,

the latter in cooperation with DFVLR (Deutsche Forschungs- und Versuchsanstalt für Luft- und Raumfahrt) in Oberpfaffenhofen, Germany, whose people can take measurements from altitudes of 10 to 12 km. Low elevation angles are used to get enough molecules into the path. A study involving an experiment with the proposed space laboratory is scheduled for 1984. In this study, a 3- or 4-channel receiver operating at 118 to 270 GHz will be used to measure and quantify the atmospheric concentration of oxygen, water vapor, ozone, carbon monoxide, and other substances. The instrument will look in a direction tangential to the earth and is expected to detect concentrations of 1 in 10^6 . A new, sensitive receiver is being developed for this purpose by Dr. K. Künzi and his staff at Berne, who are working with Bell Labs on a low-noise down-converter using a Schottky-barrier diode mixer. So far, a system working up to 230 GHz has given a measured system noise temperature of 4,000K; this is expected to rise to 5,000K at 270 GHz. Fine frequency discrimination is planned through the use of SAW (surface acoustic wave) filters giving 500 adjacent channels with 1 MHz resolution.

Schanda advocates aperture synthesis in the frequency domain for airborne radiometric observations. In its simplest form, this method would use two separated antenna apertures which give an ambiguity-free low-resolution beam (response) at a relatively low frequency when the apertures are spaced half a wavelength or less apart, and a high resolution with many ambiguities at a relatively high frequency. The use of a wide band of frequencies permits one to obtain ambiguity-free high resolution. Problems arise due to the low antenna gain and its variation with frequency as well as the frequency dependence of the emissivity and its variation with the nature of the terrestrial surface media.

After completing our visit to the university, Besson accompanied me to the Research and Development Division of the Post Office (PTT—Post, Telegraph, and Telephone), also in Berne, to visit their microwave group. The staff of that division consists of about 250 people, equally divided into those with degrees, e.g., engineers, equivalent to BSc or higher; those who left school at the age of 16 and then attended a technical high school (HTL, Höhere Technische Lehranstalt) for 4 years; and so-called professionals who include technicians, secretaries, and administrators.

The Post Office in Switzerland is a federal institution, responsible for general communications as well as mail.

Included in its responsibilities are not only communication links, but also, as a carryover from the past when it operated the horse-drawn mail coaches, the operation of the cross-country bus transportation service.

I met with the head of the microwave group, Mr. Christian Steger, and his associate, Mr. Bernard Eicher. Steger has 6 people on his team. He is in the enviable position of having ample funds available; his major restrictions are those imposed by strict staffing ceilings. Steger's work primarily covers control of incoming telecommunications and other hardware and its acceptance tests. He is involved in measurements over all ranges of frequency up to 40 GHz. Present specifications for impedance matching in operating telecommunication systems are exceedingly tight since multiple mismatches can cause echo (time-delay) distortions. The test equipment obviously must be even better. Steger and his team have developed high performance components for the measurements. Of particular interest were coaxial-to-waveguide transitions which could be adjusted to a VSWR (voltage standing-wave ratio) of 1.01 over the band 3.3 to 4.9 GHz; high-power, coaxial attenuators adjustable in half-dB steps or smoothly variable, with flat response over the band 1.5 to 18 GHz and a VSWR of less than 1.2; and directional couplers in waveguide using many small coupling holes, giving better than 50 dB directivity.

Steger has tested various precision connectors and been able to measure leakage from them as low as -120 to -130 dB (i.e., 1 part in 10^{12} to 10^{13}). He participates in international discussions and standardization meetings and has proposed a method for measuring a small mismatch by introducing a relative large mismatch many wavelengths in front of it. The reflection coefficient variations are then observed as the frequency changes. The two reflections come in and out of phase as the intervening (long) line length changes by an integral number of half-wavelengths (due to the change in frequency) and a ripple is therefore observed which has peak-to-peak excursions of value twice the (small) reflection coefficient and can be accurately measured.

The two institutions that I visited in Berne, concerned with very different studies, were both at the forefront of their fields; the university, carrying out remote sensing and interpretation, with special emphasis on correlation between emissivity and reflectivity; and the Post Office, performing precision

measurements with a dedication to precision true to Swiss reputation and tradition. (T.C. Cheston)

MEDICAL SCIENCES

THE PUBLIC HEALTH LABORATORY SERVICE INTERNATIONAL WORKSHOP ON CAMPYLOBACTER INFECTIONS

The UK Public Health Laboratory Service (PHLS) hosted the International Workshop on *Campylobacter* Infections, which was held on the 24th to 26th of March at the University of Reading. There were approximately 150 participants.

Although it was sponsored by the PHLS of the UK, the workshop was truly international in scope with most of the European countries well represented, as were the US, Canada, Japan, Israel, and Africa.

The workshop was opened with the presentation of an invited lecture by Dr. J.P. Butzler (Univ. Hospital of St. Peter, Brussels). Dr. Butzler, one of the pioneers in the field, is credited with the initial development of simplified isolation techniques for this fastidious, microaerophilic organism. In his remarks, he summarized the history of the research on *Campylobacter* infections. Originally known as *Vibrio fetus*, these organisms have long been familiar to veterinarians as a cause of infertility and abortion in cattle and sheep. Two similar but distinct organisms, *V. coli* and *V. jejuni*, were found to cause enteritis in calves and pigs, respectively. The organism was first associated with human disease by Vincent in 1947. Based on the work of several early investigators, particularly that of King relating to the characteristics of *V. fetus*, Sebald and Veron in 1963 designated a new and distinct genus—*Campylobacter* (Greek for curved rod). In 1973, Veron and Chatilain reported on their work in the taxonomy of *Campylobacter*; they divided the genus into three species, *C. fetus*, *C. coli*, and *C. jejuni*. *C. coli* and *C. jejuni*, which cause a moderate to severe enteritis in humans, are considered the most important.

The first workshop session was devoted to geographic epidemiology. Dr. M.J. Blazer (Communicable Disease Center, Atlanta) described a series of *Campylobacter*-caused enteritis outbreaks during 1980 in the US and emphasized the importance of *Campylobacter* in enteric disease in the US. Currently, the prevalence of that cause of the disease

is significantly greater than either *Salmonella* or *Shigella*-caused enteritis, particularly in the 10-to 25-year-old age group. A similar report from Dr. T. Itoh (Yoshitok Metropolitan Research Laboratory of Public Health, Tokyo) stated that the frequency of *Campylobacter* enteritis among adult diarrheal cases is second only to *V. parahaemolyticus*. He further emphasized the importance of *Campylobacter* enteritis in several Southeast Asian countries. This same finding was emphasized throughout the session. Reports from Africa, Bangladesh, Greece, Sweden, Hong Kong, England, and several other countries indicated that *Campylobacter* enteritis has a worldwide distribution and is more prevalent than either *Salmonella* or *Shigella* enteritis. An intriguing point became evident as the workshop continued: the mean age for victims of enteritis in the underdeveloped countries is 2 to 5 years, while the mean age in the developed countries is 18 to 25 years. The discussion of this observation brought forth several conjectures as to the cause (or causes), but the question of cause remains unanswered.

The session on molecular biology produced several interesting papers, including one by Dr. P.E. Taylor (Hospital for Sick Children, Toronto). Dr. Taylor indicated that several strains of *C. fetus* ssp *jejuni* appear to possess drug-resistant plasmids which are transferable to nonresistant strains. The most completely characterized of these plasmids carries tetracycline resistance and has a molecular weight of 3.8×10^7 daltons. While only 190 of the tested strains were erythromycin-resistant, it is also believed that it is plasmid-mediated in contrast to chromosomally-mediated ampicillin-resistant. An interesting discussion of treatment protocols for *Campylobacter* infections followed Taylor's paper. Two papers, one by Dr. R.A. Austin (Univ. of Victoria, British Columbia) and one by Dr. M.A. Curtis (County Hospital, Hereford, UK) suggested that cellular fatty acid profiles, as identified by gas-liquid chromatography, are very useful in distinguishing *Campylobacter* species. This is particularly relevant, due to the confusion which exists concerning the nomenclature and biotyping of these organisms (as discussed later).

Although there were several papers presented on the development of *in vivo* and *in vitro* model systems to study the mechanisms of human campylobacteriosis, no completely satisfactory system appears to exist; the need for further research in this area was indicated. One of the

mechanisms of the disease in humans is the adherence of the bacteria to host epithelial cells. Dr. F. Dijs (Free Univ. of Amsterdam) examined several human strains of *C. fetus* ssp *jejuni* but failed to demonstrate the presence of pili (adherence organelles), although the strains did nonspecifically agglutinate the erythrocytes of several animal species.

The session on serology and serotyping emphasized the complex and controversial nature of *Campylobacter* serology. One of the central themes of the presentations was the lack of a common antigen which will identify all *C. fetus* ssp *jejuni* strains. Several serotyping schemes were presented, including those by Dr. S.L. Penner (Univ. of Toronto), Dr. J.D. Abbott (Withington Hospital, Manchester, UK), Dr. S. Lauwers (Free Univ. of Brussels), Dr. H. Lior (Laboratory Centre for Disease Control, Ottawa), and Prof. D.W. Lamba (East Tennessee State Univ., Johnson City). Although there are significant differences in the various serotyping schemes, there was general agreement that there is a great deal of antigenic diversity within *C. fetus* ssp *jejuni*, approaching that seen in *Salmonella*. The number of serotypes varies from the 23 types of Prof. Lamba's to the more than 50 serotypes reported by Dr. Lauwers. Investigators currently working in this area organized a special study group and held a meeting later during the week. The objectives of the group were to coordinate the study of *Campylobacter* serology and eventually to standardize the serotyping scheme. The group further agreed to meet later this year to update the serotyping schemes.

During the session on taxonomy, it was evident that there is also some confusion. Dr. M.B. Skirrow (Worcester Royal Infirmary, Worcester, UK) presented a paper which was one of the highlights of the session. Based on the current edition of Berge's Manual, the catalase-positive, thermophilic *Campylobacter fetus* is divided into four subspecies: *C. fetus jejuni*, *C. fetus coli*, *C. fetus fetus*, and *C. fetus intestinalis*. The US, in particular, has adopted this nomenclature; however, in Europe, *C. fetus jejuni* and *C. fetus coli* are considered as separate species, viz., *C. jejuni* and *C. coli*. This nomenclature was assigned to these organisms by Veron and Chatelain in 1963 and is considered by the Europeans to have historical priority. The differences have led to confusion, particularly in the *Campylobacter* literature. Dr. Skirrow suggested the following classification based on nalidixic acid sensitivity, hippurate hydrolysis, and H₂S production

in iron-containing media:

	Nal	Hip	H ₂ S
<i>C. jejuni</i> (biotype 1)	S	+	-
<i>C. jejuni</i> (biotype 2)	S	+	+
<i>C. coli</i>	S	-	-
Nalidixic acid-resistant thermophilic <i>Campylobacter</i> (NARTC)	R	-	+

Legend:

S : sensitive + : positive reaction to the test
R : resistant - : negative reaction to the test

C. jejuni (biotype 1) is the organism most often associated with human enteritis; *C. jejuni* (biotype 2) and *C. coli* are only occasionally associated with human disease, and the NARTC strains have yet to be found in conjunction with the disease in man. Several other presentations supported this classification system and it was the consensus of the meeting that this nomenclature be adopted, although official adoption must await further amplification and acceptance. During this session there was an extensive discussion of media for both isolation and enrichment. Several new techniques were reported which will definitely improve the isolation and recovery of *Campylobacter* from clinical material.

In the session on pathogenesis, several experimental infection models, including one by Dr. B.D. Firehammer (Montana State Univ., Bozeman) were presented. In his studies, Firehammer infected lambs with human strains of *C. fetus jejuni* but failed to produce diarrhea. The lambs did develop pathological changes in the intestine similar to those found in human biopsy material, but much less severe. He was more successful in infecting calves: 10 of the 12 treated calves developed minimal clinical signs of enteritis. He also reported his inability to produce convincing evidence of enterotoxigenicity in several additional studies. Similar findings were reported by Dr. J.F. Prescott (Ontario Veterinary College, Guelph, Ontario). He failed to induce diarrhea in germ-free piglets, while succeeding in producing a very mild enteritis in germ-free beagles. Other presentations dealt with experiments using several different species of animals, including rhesus monkeys, rats, and mice. It was evident from these papers and subsequent discussions that a suitable experimental animal host for *C. fetus jejuni* strains of human origin has not yet been found. It would appear that, in some cases, those strains capable of causing severe enteritis in man are not capable of causing the disease in other animals.

It was appropriate that both the initial and final sessions of the workshop dealt with epidemiology. It is this area which has stimulated the most interest and research in recent years. The simplest method of summarizing the epidemiology of *Campylobacter* is to use the old adage "seek and ye shall find." This ubiquitous organism appears to be a common inhabitant of man's environment and both massive and sporadic outbreaks have been traced to diverse sources. The animals that man utilizes for food appear to be the greatest source of *Campylobacter*, in particular, chickens, cattle, and pigs. A typical example was the outbreak in a military camp reported by Dr. J. Oosterum (Antonic van Leeuwenhoeklan, Bilthoven, The Netherlands) and traced to the ingestion of contaminated raw hamburger. Several papers indicated that pets (nannies and kittens) are typically a common cause of sporadic outbreaks in families. Dr. P.H. Jones (Central Public Health Laboratory, London) described a large outbreak involving 2,500 cases of enteritis in a single school district due to improperly pasteurized milk. This outbreak and others related to unpasteurized milk are particularly significant in light of the current health-food craze which includes the consumption of "natural" unpasteurized milk. Untreated water, contaminated by sewage, is also known to be an important source of *Campylobacter* disease.

Present plans call for another workshop to be held in 1983 in Southampton, UK. If the success of the recent meeting at Reading is any indication, the 1983 meeting should be very exciting for workers in the field. (Bruce Merrell, Microbiology Branch, Naval Medical Research Institute, Bethesda, MD)

OCEAN SCIENCES

OCEANOGRAPHY AT LOWESTOFT

The Fisheries Laboratory at Lowestoft, on the coast of the North Sea, is a branch of the UK Ministry of Agriculture, Fisheries and Food (MAFF). Some of its activities are discussed in ESN 34-3:119 (1980). Its main objective is to study all aspects of the marine and estuarine fisheries of England and Wales. Its companion laboratory at Aberdeen, Scotland, is responsible for the study of the marine and sea loch fisheries of Scotland (ESN 34-6:293 [1980]). The Lowestoft laboratory, which is directed by Dr. A. Preston, is a large one, with

a total staff of over 250 persons. Most of its funding comes directly from MAFF, but some also comes from other governmental agencies to support specific marine research projects. The laboratory grew rapidly from the mid-1960s but has now leveled off at its present size.

The laboratory is closely associated with the nearby University of East Anglia in Norwich. Usually, two or three graduate students from the University of East Anglia are in residence in Lowestoft doing PhD thesis research. For the most part, they are supported by grants from the Natural Environment Research Council. From time to time personnel from the laboratory teach at the university. Frequently, foreign students and professors spend up to a year at the laboratory, usually with support from the UN Food and Agriculture Organization (FAO).

The laboratory operates the 47-m middle-water side trawler *CLIONE* and the 41-m middle-water stern trawler *CORELLA* (Latin for sea squirt). These vessels are designed to work in the North Sea and on the UK continental shelf, but the *CLIONE* has made voyages as far afield as Iceland and the Canary Islands. The vessels are used primarily for exploratory fishing and for studying fish ecology and migration. In addition to these two large vessels, the laboratory has three additional, smaller vessels. About 50 days of ship time are allotted each year to the Aquatic Environment Protection Section. This article is primarily devoted to the research program in this section, whose scientific staff of 15 members works on chemical and physical oceanographic research. The scientific staff is assisted by a research support group of technicians, electronic engineers, and computer specialists.

During the decade prior to 1966, the laboratory had dropped its deep-sea oceanography programs in favor of marine environment studies related to commercial fishing, and advising the government on industrial waste disposal in the oceans. Now, the UK is committed to a major program to obtain much of its electric power from nuclear power plants, and this has cast deep-sea oceanography programs in an entirely new light. As a by-product of the nuclear-power program, radioactive spent fuel wastes have been piling up in land storage sites. In 1976 a major program was set up at Lowestoft to determine the feasibility of disposal of radioactive wastes on or in the bottom of the Eastern North Atlantic. Since then, the Aquatic Environment Protection Section in Lowestoft has been striving to get back into deep-sea oceanography.

About 70% of its efforts are now devoted to studying problems related to deep-sea disposal and finding sites in the Eastern Basin of the North Atlantic that would be suitable for long-term disposal of highly radioactive wastes. It is also carrying out radiological studies with the help of biologists. In this program, the staff is cooperating with the Lamont Geological Observatory in the US, the French oceanographic center at Brest (ESN 34-10:283 [1980]), the UK Institute of Oceanographic Sciences, and other institutions.

The objective of the research is to understand the circulation from top to bottom and the diffusion and advection processes that will move and disperse radioactive materials that are released on the bottom. The next step will be to develop the ability to predict the concentrations (averages, extremes, and persistence) of radioactivity throughout the water column from known sources on the bottom. This will take a long time; the measurement effort will need to extend over a decade to provide an understanding of the variability of the processes that will distribute radioactive material.

A good deal of time is being devoted to mathematical models. The researchers want to develop a 3-D model of the circulation of the North Atlantic for assessing, at time scales of 30-1,000 years, the resulting distribution of radioactive material (in both time and space) from releases of such material on the bottom in various places in deep water. The knowledge gained will aid in determining what field studies are most important. The 3-D Atlantic model has been developed to the point where the full diagnostic calculation is now being compared to observed density distribution. Two-dimensional meridional models of the basins in the North Atlantic will be used to obtain ventilation times of various regions, i.e., the times taken for materials in solution to pass through the areas. Various shelf-edge processes will be modeled if it is found that they may be important in moving or dispersing radioactive materials.

The highest priority in field work will be given to tracer studies in order to measure actual diffusion rates over a wide range of scale in both time and space. These measurements will be done in collaboration with US scientists and with scientists from other UK laboratories and European countries. Plans for these studies include a long-term (1 year), large-scale (circa 2,000 km) deep-sea tracer experiment; a long-term (1-2 year), large-scale float-track experiment in

the North Atlantic; and at least one "float-cluster" experiment. Second priority will be given to studies of the circulation of the North Atlantic in order to quantify the various transport processes that occur. These efforts will include: the maintenance of current metering stations for periods of at least 4-5 years (the station positions will be located so that they monitor important aspects of the general circulation pattern in the North Atlantic), water column sampling of all kinds at and around the current meter stations in conjunction with the current measurements, and studies to identify transport processes found at the shelf edge and the long-term circulation pattern of the region lying within 80 km of either side of the shelf-break.

Nepheloid layers (clouds of suspended material) will be surveyed in the water column in the region within 160 km of the shelf edge between 45°N and 50°N. If they are found to be an important feature of the water column, their importance will be assessed in relation to eventual distribution of radioactive wastes.

Specific studies will be made in the region of sites already identified as being most suitable for dumping high-level radioactive wastes. The surveys will include, but will not be limited to, water column characteristics, current measurements over 12-month periods, bottom coring, detailed bathymetric surveys, and trapping of fish and invertebrates. The laboratory is already maintaining a watching brief on some extant dumping sites for low-level radioactive wastes.

Chemical oceanographers and fishery biologists will carry out radioecological studies. Many of the longer-lived nuclides which predominate in low and intermediate-level wastes, and particularly those in highly radioactive wastes, are isotopes which are man made. The range of data is not extensive; it is therefore extremely difficult to predict their behavior in the environment. The Irish Sea contains small amounts of these materials which are being discharged from the Windscale nuclear power plant. This provides the researchers with an opportunity to study the materials' interaction with biotic and abiotic components of the marine environment. Studies in the laboratory, the Irish Sea, and in deep water will be carried out in an endeavor to determine the effect that long-lived radionuclides have on the deep sea environment. Food-chain studies will be carried out to determine potential pathways of radio-

active material back to man via the ingestion of marine products, with particular emphasis being placed on those means which are significantly more direct than are purely physical processes.

Some of the projects the laboratory initiated or continued work on in 1979/1980 are discussed below.

TIROS-N AVHRR (Advanced Very High Resolution Radiometer) satellite-derived imagery was used to resolve delicate features of the ocean surface temperature distribution which were only barely detected in previous imagery. Three cloud-free images of the sea-surface temperature taken in May, June, and July of 1979 over the Bay of Biscay revealed a narrow band of cold water. The band slants from northwest to southeast, from Porcupine Seabight (southwest of Ireland) to 45°N in the Bay of Biscay. It parallels the upper part of the continental slope near the shelf break and is thought to be due to upwelling of cold subsurface water. This upwelling may be due to interaction between shelf topography and Kelvin or other waves propagating along the slope. Ground truth measurements taken of the sea-surface temperature trace across the shelf break revealed a drop of temperature of 3°C at the break. There is limited evidence of enhanced biological productivity in the area of the upwelled water. (Dr. Robin Pingree [ESN 34-8:401 (1980)] had also noted the line of upwelled cold water at the shelf break.)

There are a large number of seasonal thermal fronts in the waters around the British Isles [ESN 34-8:401 (1980)], and ESN 34-5:237 (1980)]. These fronts and eddies associated with the fronts are known to be biologically rich. The advent of TIROS-N with its ability to resolve sea-surface temperatures with a horizontal resolution of only 4 km [ESN 34-5:235 (1980)] has brought the biologists and the oceanographers of Lowestoft into considerable involvement with remote sensing studies.

There are many dumping areas in the shallow water around the coasts of England and Wales where sewage, sludge, and industrial wastes are disposed of. The laboratory has a long-term project of making current-meter measurements on established or proposed dumping sites to determine where the water currents will move the pollutants.

The Fisheries Oceanography Unit took a major role in the French "Turbillon" (eddy) experiment which is described in ESN 34-10:483 (1980). This combined neutral-density-float, current-meter and temperature-salinity study of a large eddy located in deep water about

300 km west of Brest gave a fairly thorough description of the mechanics of the eddy. Part of the Lowestoft laboratory's interest in studying the eddy was to learn whether the eddies played a role in vertical water movements. It will be several years before the data are completely analyzed and the results are published.

A continuing study of eddy climatology of the North Atlantic is aimed at producing 3-D plots of eddy kinetic energy per unit mass (cm^2s^{-2}) and has resulted in the development of four charts of the Atlantic Ocean covering depth layers 0-800 m, 800-1,800 m, 1,800-3,800 m, and 3,800-4,300 m. The data incorporates measurements of 9 months or more duration from 170 current-meter moorings. Sixty-two further sets of data from the eastern basin of the Atlantic are now being incorporated into the charts. These plots are the most complete representation of eddy climatology available for the North Atlantic. The ultimate aim of the work is the inclusion of some form of spatially varying diffusion coefficient, derived from these charts, into North Atlantic diffusion-advection models. The researchers have learned that, although the overall coefficient of eddy flux in turbulent flow (K_e) varies at different sites, there are significant regional similarities in the rates with which K_e changes with depth when data are partitioned into standard frequency bands (following the work at Woods Hole). The Lowestoft group has added to the overall data set with its own moorings in the Charley Gibbs Fracture zone across the Mid-Atlantic Ridge at about 52°N and in a quiet zone along 41°N near the Azores.

A great deal of descriptive physical and chemical oceanographic work in shallow water continues along the coasts of England and Wales. This is being done to provide data on the environment which may be related to variances in biological populations in various parts of the food chain. Data are not only available for fishery biologists working in the Lowestoft Lab, but are also furnished to many biologists and other research workers outside of the laboratory. This work along with that of other laboratories has resulted in a series of comprehensive data and oceanographic atlases of the waters surrounding the British Isles. A new black-and-white atlas has recently been distributed by the laboratory at Lowestoft; a color version of this MAFF Atlas was nearing completion when I visited the laboratory. (Wayne V. Burt)

OPERATIONS RESEARCH

THE OPERATIONAL RESEARCH EXECUTIVE AT THE COAL BOARD (UK)

The coal industry of the United Kingdom is of itself not a pertinent concern to the disciplines normally covered in this publication. The industry, however, has been exemplary in its use of operations research (OR), both historically and organizationally, and many of the practitioners of OR in the UK have been associated with the coal industry's OR efforts. For these reasons it seems appropriate to examine how OR is used and embedded in the coal industry where it has been useful and highly regarded.

The coal industry of the United Kingdom was nationalized on 1 January 1947 as a public utility called the National Coal Board or NCB (this name is applied both to the industry and to the small group of men who constitute its directors). There were ideological reasons for this action, but there were also practical reasons: the coal industry was run down and undercapitalized and needed large infusions of capital which were not available except from the government. The NCB proceeded to reconstruct the industry under the assumption that coal would continue as the major source of energy supply for the country. This assumption was eroded, however, by the era of cheap oil and by the development of gas wells in the North Sea. During the 1960s and early 1970s, the coal industry underwent a very painful contraction, resulting in the closure of many collieries; the output of the industry declined by about 50% during this period! Then came drastic price increases for oil and gas, starting in 1973, and the coal industry was forced to expand once again. This expansion was as painful in its way as the previous contraction. There is still plenty of coal underground, however, and the industry now seems to be relatively stable overall.

In 1946, even before it started officially, the NCB discussed the possibility of organizing its own operations research (OR) group. This was remarkable because, at that time, the only other civilian OR group in Europe was at the British Steel Corporation (ESN 33-3:126 [1979]). The board's action was influenced by the fact that Sir Charles Ellis, the scientific member, had worked with military OR groups during the war. It was decided to call this group of OR specialists the Field Investigation Group (FIG) and to keep OR out of the

title. The group started slowly and, by the end of 1949, had only six members. From this inauspicious beginning it has grown to be possibly the largest, and certainly the best known, OR group in the United Kingdom, and the breeding ground for most of the leaders of the profession. No less than four presidents of the OR Society, and ten occupants of OR chairs at English universities are alumni of this group. Seven of these men (Cook, Haley, Mercer, Mitchell, Rivett, Simpson, and Tomlinson) have been mentioned recently in *ESN*; (see 32-12:430 [1978], 33-9:381 [1979], 34-3:161 [1980], and 34-6:307 [1980]). Whether or not the success of this group depends on its unusual organization is hard to say; its relationship to its parent organization is described in some detail below.

In 1962 the name FIG was changed to Operational Research Branch, and in 1970 it was changed again to Operational Research Executive (ORE). It is headquartered in Harrow-on-the-Hill, a London suburb, and has subsidiary headquarters at Doncaster (Northeast England) and Leicester (in the "Midlands"). ORE now has more than 120 professionals and a budget of some £3,000,000, of which some £2,000,000 are controlled by its director, presently George Mitchell. Mitchell went to the NCB in 1960 from Cambridge University, where he had taken an MA in mathematics and had done further postgraduate work in statistics—that was the nearest thing to OR that there was at that time. (The first chair in OR was not established in the UK until 1964, when it was filled by a former director of OR at NCB, and in the early 1960s, FIG was referred to by some Americans as "the graduate school of OR in the United Kingdom.") Mitchell has recently taken over the presidency of the OR Society, a 2-year appointment.

Over a period of more than 30 years, OR has changed drastically, especially at the NCB. In the 1950s, FIG concentrated on analysis of field work, with such problems as how to sink shafts. In the 1960s there was quite a bit of technological change, and the OR Branch became much more broadly involved. In the 1970s, a period of rebuilding and fresh investment for the industry, there were many more long-term studies, and much heavier involvement of computers. But perhaps the largest change has been in the relationship of the OR people to management, which is unusual if not unique.

The Coal Board itself is a small group of men appointed by the government,

most of whom have come from the coal industry. They employ some 300,000 men, and last year the NCB produced 120 million tons of coal, which were sold for about $\$3 \times 10^9$. At the headquarters in Central London, and at the NCB's subsidiary headquarters around the country, there are the usual groups responsible for personnel, finance, marketing, mining (production), etc. There are only two levels below these headquarters groups: the collieries, of which there are about 200, and "areas," geographic and organizational entities, each of which may have ten to twenty collieries. The collieries themselves are small by US standards—typically each produces only about 500,000 tons per year, although there are some, especially the newer ones (sunk since WWII) which produce perhaps four times that much. Each area has a director, a man of considerable power, and under him are functional groups (Personnel, Finance, etc.) which also have ties to the corresponding groups at headquarters. The unusual thing about the ORE is that it reports at all levels: typically there is a team of 2 or 3 OR people at each area, teams of 2 to 6 work with each functional manager at headquarters, and, from time to time, small teams are assigned to individual collieries. There are about 30 such teams at any given time, and they report to 7 or 8 group heads who in turn report to the director of ORE. Furthermore, each team leader reports not only to a group head, but also to a "patron"—an area manager, a director of one of the functional groups, or someone else who has requested the study and justified its funding.

The method of assigning funds is also unusual, in that the size of ORE's budget is defended by its clients. After the annual budget requests are submitted, the mining manager might say "I want 10 OR people next year." When all these requests are added up, the total might be excessive, for example, 140 men. The board would then say, "Please justify why we should have 10 people at Mining," but it would say this not so much to the director of ORE as to the director of Mining! Of course such a desirable situation (from the viewpoint of ORE) was not attained without the ORE people having put great value, over the years, on keeping the patrons of their studies happy. Because they have the interests of their patrons so much at heart, it may happen, for example, that a particular area is trying to get some equipment, that the people at headquarters are resisting this request, and that two OR teams

(one at the area and one at headquarters) are carrying the brunt of the arguments, one team on each side!

British law states that the manager of a colliery must be a mining engineer. Since almost all area managers, and indeed many NCB members, have come up through the ranks, they are all engineers and can appreciate a technical presentation. I know of no other OR groups in large organizations which have so much liberty in presenting technical material to their sponsors, with the exception of the US Military.

Another unusual aspect of this OR group is that there are no specialists. Everyone is an OR worker, everyone does much of his own computer programming, and there are comparatively few highly trained mathematicians in the group. I did talk to one man who had just completed his doctorate in mathematics, and he was rather defensive about it—assuring me that people valued him for his logical ability, which had not been destroyed by his mathematical training.

I talked with several group and team leaders, all of whom had "climbed the ladder"—i.e., had come in fresh from university with little or no advanced training and had been promoted pragmatically on the basis of their usefulness to the ORE. John Fergusson, a group head, told me of some of the problems involved in planning in the South Wales district, where many of the pits are old and inefficient, and where the inefficiency is compounded by geological problems, so that on a purely technical basis it would doubtless be desirable to close some of these mines—which cannot be done for other reasons. He also described some of his group's work on "green fields", the name given to coal-containing regions where no mine shaft has yet been sunk. In addition to the obvious environmental questions which must be faced, there are significant political questions involving how to deal with local authorities and local residents, and Fergusson's group has been asked to make a major commitment toward solving these problems. I expressed surprise, in that expertise in OR would not normally be considered a qualification for such a task; but Fergusson assured me that they had important multidisciplinary capabilities. That they had been asked to contribute indicated that their expertise was indeed valued.

The most interesting group head was Josephine Mann, who joined NCB in 1969 after an academic career at Sussex University which had led to a BSc with joint majors in mathematics and economics.

She has apparently taken to OR like a duck to water, has done brilliantly, and has been advanced accordingly. Along the way she has taken the MSc in OR at Brunel University (at Uxbridge, a London suburb not far from Harrow) on a day-release program sponsored by the NCB, as have many of the members of the ORE.

Mann's approach to projects is often quite original. I was particularly intrigued by a project her people had done on manpower planning and statistics. Her clients had thought that their problem was: how can we optimally use computers to help solve manpower problems? Mann, on the other hand, believed that their real problem was the need for better and more relevant information, and they were actually being buried by computer output without being able to find the useful information that was in it. So she made a study to see what part of the computer output was being used. She did not simply ask people what they were using because she was sufficiently experienced to know that they tend to respond with what they think they ought to be using; so she instead made a careful study of the pages of output to find out which ones were dog-eared! As it turned out, there was a lot of useful information in the system which was not being used; to improve the situation required only deleting some outputs, adding others, and giving people access to the computer to develop their own outputs.

Another tale of practical OR: there is a great deal of complex mining machinery underground, and studies of reliability, preventive maintenance, and the like have been going on for a long time. At one mine, there were significantly fewer breakdowns of this machinery (and hence more coal being extracted) than at other mines. The managers of the other mines attributed the difference to differences in geology, and to a wide variety of other causes. What the OR team discovered was that the more efficient mine had a "Roving Maintenance Team" (RMT) which did preventive maintenance when it was not helping with major jobs. Apparently the RMT was doing such simple things as oiling the machinery—things which the normal operating crews would never admit they hadn't done, but which nonetheless seemed to have been neglected. The solution was obvious—not to upbraid the operating crews, because that simply doesn't work, but to establish RMTs at the other mines.

Another study about which Mann told me was of voluntary wastage (wastage

is a British word meaning loss of manpower due to people leaving their jobs); that is, wastage due to reasons other than sickness, death, retirement, or being declared redundant (a British term meaning discharged because there is not enough work to go around). By regression analysis, voluntary wastage was determined to depend primarily on the availability of alternative employment (as determined by the unemployment rate) and on the wage differential between miners and workers in other trades—mining is not a very pleasant occupation, and miners' wages have always had to be somewhat higher than those of other workers of comparable skill and training. The first regression coefficient was ten times that of the second; that is, a change of 1% in unemployment rate had the same effect on voluntary wastage as a change in wage differential amounting to 10% of the wages. A set of graphs representing these conclusions was prepared and sent to all areas to help them to control wastage: usually wastage is discouraged because of the expense of recruiting and training replacements, but on occasions when there is an excessively large workforce, voluntary wastage is to be preferred to redundancies (which in the UK are accompanied by quite large payments in most cases).

Many of the studies require some understanding of how coal is mined. The coal occurs in seams, typically three to fifteen feet high, a few feet wide, and sometimes thousands of feet long. Channels are normally cut along both sides of the seam for transport of workers, tools, equipment, and especially of the coal which is being removed. Miners then employ complex and expensive equipment to work at the face of the coal seam (and "working at the coal-face" has become a common slang term among UK OR workers to designate practical, dirty-hands work as distinguished from theory and desk-bound analysis). This equipment often can cut away the coal more rapidly than the channels can be cut along the sides; if this expensive apparatus has to wait, a significant cost is involved. An alternative is to cut the coal by "retreating" instead of advancing; in this procedure, the channels are cut all the way to the end of the seam, and track is laid in them, before any coal is cut, and then the far end of the seam is removed first. These two possible courses of action present a clear opportunity for a cost analysis of the type which OR has classically been very good at, and, indeed, such analyses were made early in the OR effort at NCB. More recently, such

analyses have been improved and simulations developed which allow one to analyze various methods of attacking particular seams, including the advance-or-re-treat decision.

It turns out, in fact, that a wide variety of different methods of attacking a seam are feasible, and it is a matter of sophisticated analysis to determine which is best. In the first place, most of the coal in a mine is never removed—in general the recovery rate is about 40%. I was appalled by this, but was told that the rate may be even lower in deep mines in the US. If the seam is too thin (less than seventy centimeters) it cannot be mined economically; if it is too thick (more than four meters), the equipment cannot get at it all at once, and anything above the equipment's maximum capability has to be mined separately or abandoned. Furthermore, great columns of coal must be left to support the roof of the mine and to control subsidence (apparently it is cheaper to leave in coal supports than to remove all the coal and hold up the ceiling with concrete or wood). But as long as there is enough coal underground to last for hundreds of years (and there appears to be), there is little motivation to recover a larger fraction of the coal from the old mines at high cost when it is easy to open newer mines at lower cost. At any rate, elaborate computer simulations have been developed for such planning.

Typical of these simulations is one called Geoplan, described to me by Malcolm Mitchell (no relation to George Mitchell) who works as head of a group (of three people) on exploration, in an OR team (of eight people) on colliery planning and exploration. He graduated from Warwick University in 1973 with a BSc in Economics, and went to NCB. He subsequently earned the MSc in OR at Brunel. Mitchell is interested in reserves assessment—determining the quality, quantity, and distribution of underground coal from borehole information (in a green field). The geologists draw maps with "isopachytes," lines of equal thickness of the coal seam, which is very time consuming. A computer is able to do the same job better and more quickly, although the output is always presented to the geologists for approval and possible modification. From this computer-drawn map, another map is made showing recoverable reserves per square kilometer. A geologist doing this same chore by hand would use bigger squares (than one km) and would still take a very long time; Geoplan churns out maps with a number in the center of each 1-km square

representing the number of recoverable tons of coal. This has been done, for example, in a region of northeast Leicestershire where there are five workable seams, in an area of about 10×20 km, from which it is planned to draw about 7,000,000 tons of coal per year for the next 60 years from three mines which are being developed. Normally one would first sink shafts near the richest reserves, but it may be desirable to balance good and poor quality coal, or to postpone work on the best faces in order to even out production.

Nicholas Goller, the mathematician mentioned above, has been working on a computer program, called Adman, for manpower planning, including recruitment and training, wastage, retirement, etc. He told me about the kinds of practical problems that one faces in developing such a simulation. For example, there was a particular colliery where facemen were trained very quickly and efficiently; as a result, recruits tended to go to that colliery initially, and then to move on to other collieries after they had completed their training. The area manager liked this system, which provided him with a constant supply of trained workers, but the colliery manager who was subjected to an abnormally high turnover rate, did not like the system. The latter, to keep the area from stealing his men and forcing him to waste his resources on training, made unreasonably high estimates of his manpower requirements. The result, of course, was that the predictions which came from the computer simulation (with these invalid inputs) indicated that the plan was infeasible. But with reasonable inputs, Adman does a fine job, not only of predicting, but of permitting sensitivity analysis—that is, allowing people to vary their assumptions or recommendations and determining the effects. There was initially some resistance to the use of this model, but when the program was changed so that the computer output was in the familiar form of the output of the old manual system, it became widely accepted and is now used all over Great Britain.

Still another simulation was described to me by Christopher Bumstead, who went to the NCB after earning a BSc in Math at Manchester (and he has almost finished the MSc in OR at Brunel). This one handles "coal preparation," the term used for washing the coal and separating it from dirt after it has reached the surface. It appears that there are a number of different flow circuits, conveyer belt sizes, methods of operation, and the like, as well as different objectives in the preparation

(including the extent to which one desires to have low-sulfur or low-ash content as well as the more obvious objectives). The model incorporates sensitivity analysis, so that one may examine the effects of changes in the system itself or in the quality or quantity of coal delivered to it from the mine. The model is now being widely used, not only for designing new coal preparation plants, but also for answering questions which may arise concerning when a preparation plant should be changed as the mine itself matures, or whether suggestions that have been made for improvements of existing preparation plants are in fact worthwhile.

Because of the tremendous background of analysis done by the ORE over the years, and the number of models which have been built and computerized, there are "suites" of models for all sorts of areas from planning to production and marketing.

The studies described in this article have been presented because they were the most interesting ones about which I heard; the last ones, on simulation models, were perhaps the most typical. One clearly cannot describe in a brief article the work, over many years, of more than 100 highly educated, highly motivated, and highly individualistic OR workers in an unusually decentralized organization. What is clear is that this is an extraordinarily successful group because what it does is extraordinarily useful to the larger organization of which it is a part. (Robert E. Machol)

OPERATIONS RESEARCH AT SWISS SCHOOLS— PART I, ENGINEERING SCHOOLS

Switzerland has only 6,300,000 people; less, say, than the state of Florida. Yet it supports seven universities, plus two engineering schools (the Ecole Polytechnique Fédérale de Lausanne [EPFL] and the Eidgenössische Technische Hochschule [ETH] in Zürich) and one school of administration (at St. Gallen). This is probably more than the optimal number. Freiburg, for example, is only 30 km from Bern in one direction and only slightly farther from Lausanne and Neuchâtel in other directions, and each of these three cities has a university. Freiburg also supports a university, which is necessarily quite small, and therefore restricted in the kinds of research it can do. If one were designing an optimal set of locations for the universities of the country, one would probably not site a university in Freiburg; but it has a long and honorable history, and

in addition, both domestic politics and religious considerations argue for its continuance.

This article deals with the two engineering schools, EPFL and ETH. Next month, Part II will conclude with discussions of the school of administration at St. Gallen, and with the four (of the seven) universities at which there is significant OR effort.

Lausanne

The EPFL was originally the engineering faculty of the University of Lausanne, but became a separate institution in 1969. It now has some 2,000 students. I visited the Mathematics Department there, which has some 15 faculty members and some 60 assistants and research assistants, many of whom are doctoral candidates. It awards about 4 or 5 doctorates a year, mostly in pure mathematics. The operations research activity is confined essentially to the work of two professors, Dominique de Werra and Thomas Liebling, and their 7 or 8 assistants. (An earlier article in this issue of ESN [see page 189] deals with research within LEMA, another department within the EPFL.)

De Werra is acting head of the department this year, but operates normally to a considerable extent independent of the rest of the department. He is one of the leading lights of Swiss operations research and is well known in the international OR community. His work has been described three times recently in ESN [33-8:340 [1979]; 33-10:431 [1979]; 34-9:460 [1980]]. He took his doctorate in physics in 1965 at the University of Lausanne (the EPFL did not exist at that time) and still insists, "I'm not a mathematician, I'm a physicist." But he does manage to publish highly theoretical papers on graph theory in mathematical journals.

I was fascinated by the way in which de Werra is able to combine exceedingly arcane theory with exceedingly practical applications. For example, consider a polyhedron defined by $\{x | Ax \leq b; x \geq 0\} = P$. Consider any integer vector x in P and let $k > 0$ be a given integer. Then there exists a set of y_i ($i=1,2,\dots,k$) such that $x = y_1 + y_2 + \dots + y_k$; $y_i \geq 0$ and

$\left\lfloor \frac{1}{k} b \right\rfloor \leq Ay_i \leq \left\lceil \frac{1}{k} b \right\rceil$ where $\lfloor \cdot \rfloor$ means "the next smallest integer to" and $\lceil \cdot \rceil$ means "the next largest (for each component of the vector)". De Werra has proved that this theorem is true for all polyhedra in which the defining matrix A has a property known as total unimodularity, and then found the following application

for it. Assume that one has a large number of teachers who must be assigned to a large number of classes. Teacher A, for example, must meet class 1 three hours each week and class 2 one hour each week; teacher B must meet class 1 and class 2 one hour per week each; and teacher C must meet class 2 four hours per week. The corresponding graph is shown in the figure below. The real situation would, of course, be far more complicated, with many teachers and many classes.

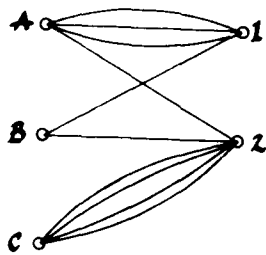


Figure 1. A graph showing weekly schedule requirements between instructors and classes.

It is desired to balance the assignment of teachers to classes to days, in the sense that the minimum number of hours per day which any teacher teaches differs from his maximum hours per day by not more than unity. For example, every teacher who must teach more than 5 and less than 10 hours a week is to be assigned in such a way that he teaches not less than one and not more than 2 hours each day; if he teaches between 10 and 15 hours, then his schedule must have not less than 2 and not more than 3 each day; etc. And the classes should be balanced in the same sense: they must be balanced among the days in such a way that there is an integral number of hours in each day, and the maximum number of hours and the minimum number of hours differ by not more than 1. This scheduling problem (with 5 days per week) is an example of the theorem for the case when $k = 5$. Here the x s consist of the total assignments of the professors and the y s consist of the daily assignments, and similarly for classes. De Werra's theorem shows that it is possible to find such a balanced schedule. Of course the above is merely an existence theorem, that is, a theorem showing that such a schedule must exist. But de Werra also has constructed algorithms from network flow theory for finding the actual schedule which meets these balancing requirements.

All sorts of scheduling problems can be defined by graphs such as that shown in the figure, and all such graphs can be shown to be "bipartite," which means, among other things, that any cycle on the graph (starting at a node, going along various arcs, and returning eventually to the original node) contains an even number of arcs. There is a further theorem showing that any matrix representing a bipartite graph is totally unimodular. Hence, de Werra's theorem applies to all such scheduling problems.

Liebling took his doctorate in Zürich in electrical engineering in 1969, and remained at ETH until 1980 when he came to EPFL. He has done important theoretical work on combinatorics and is still interested in one of the most fascinating questions in OR, namely why the simplex algorithm works so well when, theoretically, it shouldn't. For example, he has proven some theorems which show that the expected number of vertices of a polyhedron formed by generating constraints randomly is much smaller than one might think; and also that, given a particular number of vertices, the number which are actually visited (that is, the total number of iterations during the operation of the simplex algorithm) tends on the average to be only on the order of the logarithm of the number of the vertices, and therefore again much smaller than one might expect. Problems of this nature have recently become of great interest again to operations researchers because of the excitement generated by Khachiyan's algorithm.

Liebling is also active in developing information systems for the Swiss army, but was unable to tell me much about this. He did tell me about one practical application of his work on polyhedral combinatorics: One is developing a network of pipelines to supply heat from a source such as a central generating plant to a large group of consumers, each of whom represents a node on a graph, while the pipelines themselves represent arcs on the graph. Each node is characterized by a "window" in time of its demand running from t_1 to t_2 . Specifically, before time t_1 the consumer does not require heat (because his house may not have been completely built at that time). His demand originates at time t_1 . If the supplier is prepared to fill that demand at t_1 , or at any time before t_2 , then the consumer will in fact purchase the heat from then forward. However, if by t_2 the demand has not been met, the window is closed and that consumer will never be a customer (if necessary the consumer can meet his demand between t_1 and t_2 from some alternate source such as bottled gas, but after the time t_2 he has committed

himself to some other permanent source of heat such as a different kind of furnace). There are constraints on how rapidly the network of pipelines can be built, although these constraints are somewhat subject to modification if extra money is allocated. The problem, of course, is to find out how rapidly to build the pipeline and which arcs should be completed first.

This department supplies mostly service courses; in addition there are 4 courses on operations research, each of which lasts for an entire year: mathematical programming, graphs and networks, combinatorics, and decision models. Each of these courses is given only every other year, so Liebling and de Werra each teach 1 course per year; in each of these courses there are some 15 students in the third and fourth years.

ZÜRICH

The OR group at ETH is surely the oldest and probably the largest and the most prestigious of the academic OR research groups in Switzerland. It is headed by Prof. Franz Weinberg who took his doctorate in Zürich in 1954 in the department of mechanical engineering. There was no OR taught there at that time, but his thesis was very much in the spirit of OR, applying probability theory to planning in a factory. While it would now be considered elementary, it was very exciting then. Five years later he completed the "habilitation," a post-doctoral accreditation usually required for a chair in Germany and German-speaking Switzerland. His research for that degree included application of probability theory to a unique inventory problem. Specifically, in the factory in question, certain dies and special-purpose tools had to be made from time to time to manufacture products, and these could not be used again unless those products were manufactured again. In some cases a particular product might be manufactured again within a few years, and in some cases never; but since these dies and special-purpose tools were terribly expensive, they were generally not discarded. Eventually the inventory of such devices became insupportable. Again, simple probability theory enabled Weinberg to make a considerable contribution to the problem. A very similar problem is discussed in some detail in the article "OR in Portugal," to be published next month.

When the first Swiss chair in OR was founded at ETH in 1964, Weinberg was invited to take it. The institute now has about 20 full-time researchers. Most of the 20 already have the doctorate, and some even have the habilitation, while

others are working on that advanced degree. Because there is only 1 chair in the institute, better people like Liebling tend to leave and take chairs elsewhere; but because of the nucleus of good people and the high prestige and reputation and the interesting problems on which they work, Weinberg assured me that he has little difficulty in recruiting the best people. As recently as 1979, Weinberg himself published a paper on integer programming, but his time is now mainly taken up with teaching and administration. The Institute for Operations Research, of which he is director, gives a large number of courses in OR. Furthermore, in addition to awarding 2 to 3 doctorates a year, an average of 5 to 6 of the students getting the undergraduate degree (called the diploma) spend a full semester (about 4 months) working 2 hours per week on a real project. As indicated elsewhere (ESN 32-12:428 [1978]), this consumes a great deal of instructional time.

The largest research program at the institute, taking up the time of several people, concerns the locations of civil defense shelter systems and the allocation of people to such systems all over Switzerland. Because it was of a military nature, they were not able to tell me details of this project. I did, however, talk to enough people to become convinced that many of them are combining theory with practice and performing first-rate research.

Dr. Andrés Polyméris, a Chilean who took his doctorate at ETH in OR in 1978, spends most of his time on the shelters project. He told me in some detail about typical projects which students work on for their diplomas. A particularly interesting one arose after the Swiss government required every community to install plants to purify waste water. The question asked was whether it would pay for several communities to cooperate and build a big plant, and if so exactly which communities should do so and where the plant should be. There were obvious advantages (economies of scale); the disadvantage was that pipelines must then be laid to carry the water from the central plant to each of the cities. The student assigned to the project worked out an optimal location in a region for the purification plant, together with its size and the pipelines that connected it to the other cities. While this solution minimized the total cost, it did not allocate costs to individual communities; and inasmuch as they were never able to agree on this allocation, the project was never implemented. This illustrates a classic difficulty with

student projects: the student is frequently gone before the project can be implemented, and there is no one to follow up on it.

Jürg Mayer and Heinz Gröflin, both of whom obtained their doctorates at ETH in 1977, told me about their joint research projects on distribution problems. Gröflin is applying this work towards his habilitation which he expects in 1981. (Mayer is not working on this degree; he apparently is not interested in becoming a professor, and this advanced degree is generally not otherwise required.) One of these projects involved the desirability of building a central plant to collect raw cheese on a daily basis from many small dairies, each of which produces perhaps 100 kg per day, and processing it centrally. The alternative was to perform the processing at the local dairies. The study was done for 2 regions. The recommendation in each case was to build a central plant. In one region the plant was indeed built; in the other, however, not enough dairies were willing to cooperate, and the plant was never built.

Another student project, done for the major Swiss supermarket firm of Migros, concerned the distribution of products from their bakery to their 120 stores in the Zürich region. It was in many ways a modification of the classical multiple traveling salesman problem, but with certain special constraints. For example, Swiss law prevents operation of delivery trucks before 5 a.m., and each shop had a latest hour of delivery which was between 7 and 8 a.m., the hour differing from shop to shop. The algorithm which he designed was basically not a traveling salesman algorithm at all, but a clustering algorithm which permitted the grouping of the shops such that all shops in one group were served by a single truck, after which the routing problem in each group was sufficiently small to be trivial. The algorithms were in fact implemented on Migros' computer and are still in operation.

Francisco Benito had his licentiate degree (something like a BS) from Saragossa University in Spain and was a lecturer at another Spanish university for several years before coming to ETH in 1971. He received a doctorate in 1975. Among his successful projects since that time was one on ambulance location which has been implemented both in Zürich and in Basel.

K. Hazeghi is an Iranian who has been in Switzerland for many years and who received the diploma in electrical engineering from ETH and the PhD in OR in 1973. Among the studies he told me

about was one on quantifying noise pollution around the Zürich airport leading to a solution of the problem of landing and take-off procedures there. It is a heavily political problem, with local residents complaining bitterly if the landing and take-off patterns are changed, while others complain equally bitterly if they are not changed; the politicians apparently welcomed a quantitative model which not only yielded an objectively optimum solution, but in addition, allowed them to state that their decisions were objective.

Heinz Ulrich received his doctorate in OR at ETH in 1975. His thesis dealt with the problem of the raw material supply to a lumber mill and he has been working on forestry problems ever since. These studies are generally supported by the lumber industry, but his project is partly supported by the Swiss government, which needs to know exactly which projects or industries to support and what level of support is appropriate. He is just finishing a simulation of the materials flow in the lumber industry in a region of Switzerland where forestry is one of the two principal industries (tourism is the other).

Rudolph Hug took his diploma at ETH in mathematics in 1977. He has now nearly completed his doctoral work at ETH on a cutting-stock problem. This classical problem involves being given a large rectangle from which specific smaller rectangles must be cut with as little waste as possible. Hug's work is supported by a glass factory, and applies in particular to a type of glass which, even more than other glasses, is opaque to infrared radiation and transparent to visible radiation, and therefore particularly useful as window material where energy controls are required. It is extremely expensive, on the order of 200 Swiss Francs per square meter (more than \$100/sq yd). Furthermore the material is manufactured in Germany but cut in Switzerland, so that whatever waste there is must be transported back to Germany for recovery. Hence the importance of minimizing waste. The classical algorithms of Gilmore and Gomory assume, for example, that the pieces to be cut are all similar. This assumption is not valid in Hug's problem, so new algorithms had to be developed. Hug has developed an interactive algorithm which has already been tested in a glass factory. It seems to be working very nicely.

Hans Benninger, who received his diploma at ETH in mechanical engineering in 1975, is just completing his doctorate on internal transportation in hospitals. Automated transportation systems are being

designed to carry linens, medicines, sterile instruments, food, and various other things which must be transported within the hospital. These systems consist of conveyor belts and elevators (although they could also utilize driverless vehicles). The sponsor is a Swiss company which plans eventually to install these in Swiss hospitals, but is planning to install them in the immediate future in a famous hospital in Vienna called the Allgemeine Krankenhaus which will have 2,000 beds. Benninger has built a simulation which will answer such questions as the following: (1) Where will queues form and how large will they be and, therefore, how large are the buffer zones which must be provided for them? (2) How many containers will be in use at any one time and, therefore, how many containers must be purchased? (3) What is the total transport time and how will this be modified in case queues do develop at intersections? (This last question has special relevance to food.) Of course such simulations must be run over and over again, and in this particular type of problem, where one is interested in unusual events (namely, how often will queues of considerable length build up), special techniques are required to avoid the necessity for replicating the simulation an intolerable number of times. One of the interesting aspects of Benninger's model is that he has succeeded in aggregating a detailed model to less detailed models which work rapidly. Thus, in trying to find out about the queues which build up at some intersections, it is possible to leave out of the simulation what takes place at other intersections where one knows from previous runs that queues are not likely to build up at those intersections.

Clearly an enormous amount of very practical and very good work on operations research is taking place at ETH. (Robert E. Machol)

PHYSICS

INTERNATIONAL CONFERENCE ON EXCITED STATES AND MULTIRESONANT NONLINEAR OPTICAL PROCESSES IN SOLIDS

The International Conference on Excited States and Multiresonant Nonlinear Optical Processes in Solids was held in Aussois, France, on March 18-20, 1981. With a title like that, the reader can be sure there was interesting cross-fertilization between the solid-state physicists and the optics-oriented engineers and physicists who participated.

Aussois is a peaceful, high-mountain resort nestled in the French Alps. Centre National de la Recherche Scientifique (CNRS), the NSF of France, maintains a vacation home, the Centre Paul Langevin, in these idyllic surroundings. It was here that the conference, jointly organized by CNRS and the European Physical Society, was held.

The conference covered a broad spectrum of topics including optical bistability, phase conjugation, excitons and excitonic complexes, nonequilibrium transient phenomena, and ultrashort pulse generation. Thirty-nine papers were presented, of which 15 were invited.

Prof. Arto Nurmikko (Brown Univ.) began the sessions with a discussion of the transient behavior of highly degenerate electron-hole (e-h) systems in narrow-gap semiconductors. In his experiments, short-wavelength picosecond sources are used to generate a dense e-h gas in a narrow-gap semiconductor such as PbTe. The decay of this excess population is monitored by observing the plasma dip in the transient reflectivity of a second (probing) laser beam in the 10 μ m-5 μ m wavelength region. Auger recombination is the dominant decay channel. However, the decay times (20-50 ps) are much longer than expected from extrapolations of the nondegenerate theory. Gain and laser action were also observed in thin epitaxial films of PbTe excited at low temperatures. Pulse durations of much less than 1 nsec were observed.

Dr. Ravi Jain (Hughes Research Laboratories) reviewed the nonlinear optical mechanisms responsible for degenerate four-wave mixing (DFWM) in semiconductors. The largest DFWM reflectivities ($\sim 800\%$) have been obtained through the generation of a free-carrier plasma using pulsed lasers. (Reflectivities of this order are realized because some of the energy in the high-energy pumping beam is transferred directly to the low-energy probing beam, thereby increasing the measured "reflected" energy in the probing beam.) In his most recent work in HgCdTe (at 10.6 μ m), he has observed third-order susceptibilities of more than 10^{-2} esu and CW reflection returns of approximately 1.2% at pump power levels of about 10 W/cm². Based upon his studies of many different materials, he presented an interesting empirical relationship which associates large values of relaxation times in materials with correspondingly large values of the nonlinear susceptibilities of those materials.

The nonlinear optical effects associated with excitons were discussed at length at the conference. Dr. A. Maruani

(Centre National d'Etudes des Télécommunications [CNET], Bagneux, France) spoke about the resonant enhancement in nonlinear optical mixing that occurs when photon energies are close to one-half that of the biexciton (excitonic molecule). Under these resonant conditions, very-high-order scattering processes (up to sixth-order) can be observed at relatively low power. Prof. H. Haug (Univ. of Frankfurt, FRG) presented a calculation of the intensity-dependent refractive index associated with the formation of biexcitons. Such nonlinearities may be used to observe optical bistability in micron-sized platelets of CuCl at intensities of 10^5 W/cm². Haug also claimed that e-h plasma was responsible for optical bistability in GaAs and InSb.

Dr. J.L. Oudar (CNET, France) reviewed the use of multi-resonant four-wave mixing processes in solid-state materials for the determination of ultrashort relaxation times through measurements in the frequency domain. Dr. M. Dagenais (GTE Laboratories, US) reported on CW two-photon absorption in LaF₃:Gd³⁺. Very large unexplained discrepancies were found between the Judd-Ofelt predictions and the experimentally realized two-photon relative absorption cross-sections. Polarization studies were also reported. CW two-photon absorption in InSb was discussed by Prof. D.G. Seiler (MIT, on sabbatical leave from North Texas State Univ.).

Three groups reported on the generation in semiconductors of pulses in the picosecond range. Prof. C.H. Lee (Univ. of Maryland) has generated such pulses in the 820-850 nm region by two-photon absorption of mode-locked 1.06 μ m pulses in GaAs. Prof. M.M. Salour (MIT) reported on the operation of a synchronously pumped mode-locked CdS laser. Prof. E.P. Ippen (MIT) reported on the generation of picosecond pulses by passive mode-locking of semiconductor diode lasers. Pulses as short as 1.3 psec at a rate of 0.5-3 GHz were obtained.

In the area of optical bistability, Prof. H.M. Gibbs (Univ. of Arizona) reported the observation of regenerative pulsations in a GaAs etalon driven by a CW input. These pulses, separated by 20 μ s, were the result of an interplay between thermal and excitonic contributions to the nonlinear refractive index. Dr. D.A.B. Miller (Heriot-Watt Univ. Edinburgh, UK) discussed the microscopic mechanism leading to optical bistability and two-beam optical transistor action in InSb. The basic mechanism is thought to be the creation of free e-h pairs by below-bandgap absorption (e.g., phonon-assisted absorption).

Dr. H. Winful (GTE Laboratories) presented a theory of optical bistability in nonlinear distributed feedback structures. Such structures are of interest partly because their planar geometry makes them compatible with integrated optics. He also discussed the possibility of mirrorless optical bistability through self-induced feedback in degenerate four-wave mixing. Prof. C. Flytzanis (Ecole Polytechnique, France) also considered bistability in DFWM in a Fabry-Perot cavity. Dr. J. Goll (Univ. of Stuttgart, FRG), using a quantum optics approach, started with the Heisenberg equations of motion for the exciton or the e-h pair amplitudes, the inversion, and the light field amplitude, and developed a theory of optical bistability of excitons and direct band-to-band transitions. On the whole, the sessions on optical bistability were characterized by a dearth of new experimental results.

In one of the more exciting new developments, Dr. C.V. Shank (Bell Laboratories) reported the generation of stable 90-femtosecond (femto $\equiv 10^{-15}$) pulses by "colliding-pulse" mode-locking of a dye laser. One hundred mW of average power was obtained with pump intensity of 3 to 7 watts. These pulses, believed to be the shortest yet achieved, were then used to study the dynamics of non-equilibrium carrier transport in semiconductors. Prof. D. von der Linde (Univ. of Essen, FRG) presented results on the energy relaxation of hot carriers, and the concomitant generation and decay of optical phonons (7 psec). A very fascinating talk was also given by Prof. R.G. Ulbrich (Univ. of Dortmund, FRG). In the first part, he considered different aspects of the relaxation process of e-h pairs toward thermal equilibrium with the surrounding heat bath. In the second part he discussed the saturation of the 1s free exciton resonance in an optically thin sample of GaAs. Using an optically thick (4.2 μ) sample, Ulbrich was able to see the 1s, 2s, and 3s transitions in absorption before the band-to-band absorption started to dominate. By reducing the thickness of his sample to 0.5 μ , he was only able to see the 1s excitonic level in absorption. Only 13 1s excitons could fit in the crystal. Since the sample was very thin, it was argued that there was not enough room in phase space for the 2s and 3s excitons to exist. The saturation of the 1s exciton occurred at an energy intensity of 1 fJ/ μ^2 , much lower than previously observed values. The decay time of the exciton was evaluated (30 psec) and was attributed to surface recombinations due to diffusion; the 1s exciton resonance was still seen at a carrier density of 10^{17} /cm³.

This was a stimulating conference. It provided a significant medium for interaction between the two groups of scientists involved. Plans for a follow-up conference on the same subject are not yet firm, but Prof. S.D. Smith (Heriot-Watt Univ., Edinburgh), an organizer for the meeting, commented that such a follow-up will probably occur in 1983 in either the UK or the US. (M. Dagenais and H. Winful, GTE Laboratories)

ULTRASONICS AT THE UNIVERSITY OF BATH

The University of Bath occupies a modern monolithic set of concrete buildings located outside the city. In a recent liaison visit, portions of two departments were visited and two people performing ultrasonics research were interviewed.

Prof. G.A. Saunders is the head of the School (Department) of Physics. The staff of 16 includes another full professor, H.O. Berkday. According to Saunders, it is unusual for such a small department to have two full professors; he and Berkday alternate in administering the department. Forty undergraduate students are accepted annually by the department; this is a limit set essentially by the funding policy of the university. The students specialize in those areas of physics where jobs are available: geophysics, electronics and applied physics; and are all certified as physics graduates with an option of specialization. Currently, 90 percent of the graduates take positions in industry, usually following the advice of the department.

Saunders received his graduate degree from Imperial College and then spent some time at the University of California, Riverside, in association with Prof. A.W. Lawson. Upon his return to the UK, he took a position at the University of Durham and subsequently went to Bath as the youngest professor in Britain at that time. He is very prolific in research, having produced over 100 publications. His interests are ultrasonics, high pressure measurements, third-order elastic constants and ultrasonic measurements of phase transitions.

He displayed a recently constructed apparatus for high-precision measurements of ultrasonic wave velocity which can detect changes in the transit time as small as 1 part in 10^8 at a nominal wave frequency of 10 MHz. In measuring third-order elastic constants, a uniaxial stress is applied and the corresponding change in ultrasonic wave velocity is

measured. However, it is extremely difficult to apply a relatively large uniaxial stress only, without introducing a shear component; therefore, applied uniaxial stresses are limited to those producing changes of transit time of approximately 1 part in 10^5 . This system was developed for such circumstances, where it is desired to measure small changes to a precision of approximately 1%. (Measuring a 1% change in a 1 part in 10^5 effect requires better than 1 part in 10^7 sensitivity.) In a recent article describing the apparatus (*Ultrasonics*, 18 155 [1980]), velocity measurements on Yttrium Aluminum Garnet (YAG) were reported to show a sensitivity of 1 part in 10^8 . Additional measurements on YAG to 150 MPa (1.5 kbar) with a sensitivity of 1 part in 10^5 are reported in another publication (*J. Phys. C: Solid St. Phys.* 13 6585 [1980]) in which the 6 third-order elastic constants of YAG were determined. The results of similar experiments on the third-order elastic constants of GaP have been accepted for publication in *Journal of Chemistry and Physics of Solids*.

Second- and third-order elastic constants of amorphous As were reported in another recent publication (*Phil. Mag. B.* 42 127 [1980]). Amorphous As is isotropic and therefore has 2 independent second-order, 3 third-order and 4 fourth-order elastic constants. Saunders and his students measured the longitudinal and shear wave velocities between room temperature and 4.2 K and obtained the second-order elastic constants at 294 K and 4.2 K. The temperature-dependent data are presented as wave velocity versus temperature because of uncertainties in the thermal expansion. In addition, the room-temperature hydrostatic pressure dependence of the wave velocities were measured up to 1.5 kbar in a piston-cylinder apparatus with the sample immersed in an oil pressure medium. To determine all 3 third-order elastic constants, another measurement was needed: the change in velocity as a function of uniaxial stress applied perpendicular to the direction of propagation. This latter measurement required a sensitivity of better than 1 part in 10^7 , while the others required a sensitivity of about 1 part in 10^5 . The results showed that, as with other substances, the second-order elastic constants of the amorphous material are less than those of the single crystal which is much stiffer and, in addition, the Cauchy relations for the third-order constants of the amorphous solid are not satisfied.

Coupled with a lower density, these smaller second-order constants lead to

the much lower calculated Debye temperature of 160 K for the amorphous state compared to the value of 250 K calculated from the single crystal elastic constants and 282 K obtained from calorimetric measurements in the 0.54 to 1.1 K range (*Phys Rev* 161 652 [1967]) which were analyzed as having a linear term in the temperature and a T^{-2} term (nuclear electric quadrupole) in addition to the T^3 lattice contribution. Other, more recent calorimetric measurements in the 0.35 to 0.7 K range (*Phil. Mag. F.* 38 271 [1978]) are fitted by a T^3 law and lead to an average sound velocity of 1.6×10^3 m/s (a Debye temperature is not quoted). The average sound velocity corresponding to the Debye temperature of 160 K is 1.595×10^3 m/s, and on this basis Saunders and his coworkers concluded that, similar to what has been observed for other materials, the Debye temperatures for amorphous As which are derived from elastic-constant and calorimetric considerations are in agreement and are significantly lower than the corresponding values for the single crystal.

The measured elastic constants of amorphous As and their pressure derivatives give enough information to evaluate the Murnaghan equation of state—a calculation which previously was not possible for an amorphous material. There is a distinct phase transition in amorphous As at 4 GPa, at which pressure the predicted density is 5493 kg/m^3 —within about 6% of the value of 5720 kg/m^3 for crystalline rhombohedral As.

Alloying effects in In have been studied in recent work (*J Phys Chem Solids* 40 923 [1979]) by Saunders and M.R. Madhava, who prepared single-phase Pb-alloy single crystals of varying composition and structure: 5 atom % Pb, face-centered tetragonal (fct), $c/a > 1$; 17 atom % Pb, (fct), $c/a < 1$; 75 atom % Pb, face-centered cubic (fcc). Measurements of the elastic constants of these alloys (6 constants for fct, 3 for fcc) in the temperature range between liquid nitrogen and room temperature show nearly linear and relatively small variations with temperature for individual components of the elastic stiffness tensor. However, for the 5% alloy, one of the fundamental shear modes shows marked decrease (softening). This transverse acoustic phonon which propagates at 45° in the base plane (\vec{q} [110], polarization [110]) is characterized by the shear constant $\frac{1}{2}(C_{11}-C_{12})$, which shows a strong temperature dependence decreasing to $\frac{1}{2}$ the 80 K value at room temperature. This behavior is very similar to that of an In-3.4 atom % Cd alloy where the same shear

constant falls to approximately 1/5 of its 80 K value at a temperature a few degrees below the melting point (430 K). In contrast, neither the 17 atom % Pb ($c/a < 1$) or the 75 atom % Pb (fcc) alloys show any mode softening. In fact, alloying raises this shear constant above that of the nearest pure metal (In and Pb respectively) and both alloys are nearly elastically isotropic (i.e., the anisotropy ratio $2C_{44}/[C_{11}-C_{12}]$ is approximately unity). A theoretical understanding of In alloys based on the Landau theory of second-order phase transitions has been developed, but Madhava and Saunders point out that their measurements are in disagreement with the theory (by a factor of approximately 7 for the 75% Pb alloy) and that the fcc-fct transition in In-Pb alloys is decidedly first order. At this time there is no satisfactory theoretical explanation for this discrepancy.

Mode softening has also been found in cubic La_2S_4 (*J. Phys. C: Solid St. Phys.* 13 L 697 [1980]). This material undergoes a first-order displacive phase transition to tetragonal symmetry at approximately 80 K. Contrary to the temperature dependence of many materials, Saunders and his colleagues find that C_{11} and $\frac{1}{2}(C_{11}-C_{12})$ for La_2S_4 both decrease as the temperature is lowered to that of liquid nitrogen. This happens with an accompanying change in elastic isotropy; from an anisotropy ratio of 1.07 (nearly isotropic) at room temperature to 3.7 at 80 K. Softening of the $\frac{1}{2}(C_{11}-C_{12})$ shear constant is consistent with a cubic-to-tetragonal phase change as a result of a collapse under a [110] shear. The softening of the longitudinal constant C_{11} which occurs is not necessary to explain the transition. Further knowledge can be expected from detailed neutron-scattering measurements of the phonon-dispersion curves.

The elastic constants of crystals are referred to cartesian axes (x, y, z) attached to the crystallographic axes by agreed-upon convention. Both the tetragonal and trigonal symmetries are divided as to the number of elastic constants (6 or 7) depending on the existence of twofold symmetry axes in the plane normal to the unique (z) axis. Rotation about the z axis may lead to reduction in the required number of elastic constants (increase in symmetry) if some elastic constants referred to the rotated frame vanish. This fortuitous vanishing is called "acoustic symmetry" and represents a degenerate case of the lower symmetry which is achieved by particular values of the constants.

Saunders and his student P. Blanchfield have demonstrated this effect for some scheelite structure crystals (*J. Phys. Chem. Solids* 41 1065 [1980]) and have determined their elastic constants between 4.2 and 300 K.

Dr. D.P. Almond of the School of Materials Science displayed several ultrasonics projects on which he had been working. The first was concerned with the testing of plasma sprayed coatings, which are manufactured by passing the spray material through a plasma and projecting the molten or semi-molten droplets onto the substrate by means of a high velocity gas stream. Such coatings may have a layered structure or porosity and until recently it had been assumed that they have such high attenuation as to preclude ultrasonic testing techniques. Almond and his students have measured attenuation in plasma-sprayed coatings of approximately $\frac{1}{2}$ mm thickness at frequencies from 2.5 to 15 MHz (*Ultrasonics* 19 17 [1981] and *NDT International* 13 291 [1980]) using water immersion coupling for both reflection and transmission techniques. For molybdenum and nickel aluminide coatings sprayed on aluminum substrate, they find a roughly linear relation between attenuation and thickness which has improved precision at the higher frequencies. A similar, but less precise result is found for aluminum sprayed onto a steel substrate. The data are sufficiently good that it should be possible to use conventional ultrasonic methods for non-destructive testing of coatings. For detection of bonding defects or voids, both reflection and transmission techniques were used. The reflection technique was found to be more sensitive and probably more applicable to routine testing since only one transducer is utilized.

In a second project, Almond and S. Blaire have constructed an apparatus for performing pulse overlap sound velocity measurements in liquid metals (*J. Phys. E.: Sci. Inst.* 13 964 [1980]) to a precision of 1 part in 10^4 . They have made sound-velocity measurements in liquid In to above 900 K (it decreases linearly with temperature) and have also measured sound velocity in InCd alloys across the entire composition range to temperatures above 900 K (*Australian Japan Extractive Metallurgy Symposium*, Sydney [1980] p. 449). In the alloy measurements, they have found a nonlinear dependence of sound velocity on composition; they attribute this dependence to a special bonding in InCd, which allows this stoichiometric composition to persist into the liquidus phase.

Aluminum oxide with varying proportions of Na added (β - and β' -alumina)

is a possible material for use in the sodium sulphur cell as an electrolyte. The diffusion of Na^+ in the solid state is comparable to that found in strong aqueous salt solutions. Measurements by Almond and his colleagues of the attenuation of longitudinal waves at 10-70 MHz in polycrystalline Na-enhanced alumina show a frequency-dependent attenuation peak. At 10 MHz the peak is about 1 db/cm centered at approximately 140 K. At 70 MHz the peak has grown to almost 5 db/cm and shifted to approximately 170 K. Analyzing these results as a thermally activated diffusion process gives both the activation energy (0.142 eV) and the attempt frequency (7×10^{12} Hz). The diffusion process is identified with the intrinsic conduction of Na^+ ions within the crystal-lites of the material. Full details of this experiment are to be published in *Materials Research Bulletin*.

At the University of Bath, ultrasonics research is an active, multifaceted area. It is being conducted by dedicated and competent personnel who are using up-to-date facilities. (John R. Neighbours)

NEWS & NOTES

NEW LONDON UNIVERSITY HEAD

Prof. Randolph Quirk, Quain professor of English at University College London, has been selected as the next vice-chancellor of London University. He will take office at the beginning of September when the term of the present vice-chancellor, Lord Annan, comes to an end. According to an article in the *London Times*, Quirk will be taking on the job of academic and administrative head of Britain's largest university at a time when that institution is faced by the worst financial crisis in its 145 year history. Princess Anne of the British Royal Family is the chancellor of the university. The position she holds is largely an honorary one.

ONRL STAFF CHANGES

We recently welcomed Commander Michael G. Surdyk, Command. Control, and Communications officer, who came to ONR London from the US Naval Air Station, Lemoore, California, where he was a pilot and department head with Attack Squadron 97. We also bade farewell to Dr. Robert E. Machol, liaison scientist, who returned to Northwestern University, where he is professor of systems in the Graduate School of Management. Dr. Machol had been at ONR London since January 1979.

ONR COSPONSORED CONFERENCES

International Symposium on Locational Decisions (ISOLDE II), Skodsborg, Denmark, 15-18 June 1981.

Conference on "Modification of the Surface Properties of Metals by Ion Implantation," Manchester, UK 24-26 June 1981.

Vith International Bioelectrochemical Conference, Kibbutz Kiryat Anavim, Israel, 28 June-3 July 1981.

9th International Conference on Operational Research, Hamburg, Germany, 20-24 July 1981.

International Symposium on Advances in Polymer Characterization, Durham, UK 13-17 July 1981.

International Symposium on Hydrodynamics in Ocean Engineering, Trondheim, Norway, 24-28 August 1981.

Conference on Combinatorial Optimization, Stirling, UK, 24-28 August 1981.

4th International Symposium on the Chemistry of Novel Aromatic Compounds (ISNA 4) Jerusalem, Israel, 30 August-4 September 1981.

NATO Advanced Study Institute on "Static and Dynamic Properties of the Polymeric Solid State," Glasgow, UK 6-18 September 1981.

Fifth National Quantum Electronics Meeting, Hull, UK, 23-25 September 1981.

EUROPEAN VISITORS TO THE US SUPPORTED BY ONR LONDON

<u>Visitor</u>	<u>Affiliation</u>	<u>Navy Lab./Org. to be Visited</u>
Prof. J.W.R. Griffiths	Loughborough Univ. of Technology, Loughborough . UK	NUSC (May)
Dr. D.E. Packham	School of Materials Science, Univ. of Bath, Bath, UK	NSWC, White Oak (May)
Prof. Giacomo Patrizi	Istituto di Tecnica Economica Università Degli Studi di Siena, Italy	NSWC, White Oak ONR (May)
Prof. P.C. Sabatier	Laboratoire de Physique Mathematique, Universite des Sciences et Techniques du Languedoc, Montpellier France	NRL, NSWC Dahlgren (August)
Prof. Evan Wyn-Jones	Dept. of Chemistry, Univ. of Salford, UK	NRL, Marine Physical Lab., Scripps (June)

ONAL REPORTS

R-2-81

Chemical Research at the Institut für Strahlenchemie, Mülheim, by A. Paul Schaap

The Institut für Strahlenchemie (Radiation Chemistry) which is located in Mülheim, FRG was founded in 1958 as a unit attached to the Max-Planck-Institut für Kohlenforschung (Coal Research). The Institute for Radiation Chemistry is involved in research in a variety of areas including (1) chemical effects of ultraviolet radiation, λ -rays, and high-energy electrons on organic and biological systems; (2) new methods of synthesis; (3) organic and organometallic photochemistry; and (4) theoretical chemistry.

Research at this institute on the use of vesicles to deliver inositol hexaphosphate (IHP), an allosteric effector of hemoglobin, to red blood cells (RBC) may result in procedures for dramatically increasing the oxygen release capacity of RBC. Potential applications include an improved O_2 supply to tissues under low O_2 -partial pressures in air such as at high altitudes. Preliminary experiments with rats have shown that incorporation of IHP into the RBC enables the rats to adapt to reduced O_2 partial pressures.

R-3-81

Research in Electronic/Electrical Engineering at British Universities, by Irving Kaufman

This is a summary report of research found in electronic/electrical engineering at British universities during the author's tour of duty as liaison scientist with the London Branch Office of the US Office of Naval Research, August 1978 to August 1980. The first section lists the agencies funding research in the UK with some figures on the amount of funding and its distribution. This is followed by a brief discourse on British universities, with facts relevant to the student population in EEE at universities, and a comparison of British and American graduate and undergraduate programs. Some special arrangements in relation to research are treated next, followed by a general assessment of graduate research at British universities. The final section contains, in summary form, information about the research found by the writer during his visits to 22 universities in England, Wales, and Scotland.

R-8-80

Optical Data Processing in Europe, by David Casasent

This report contains short summaries of some current activities, accomplishments, and problems in France, the Federal Republic of Germany, and the United Kingdom in the field of optical data processing. Both university and industrial research laboratories are included. In all instances, the emphasis is on optical image and signal processing.

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